Society

FOR THE

Promotion of Engineering Education

PROCEEDINGS

OF THE

TWENTY-FIRST ANNUAL MEETING

HELD IN

MINNEAPOLIS, MINN., JUNE 24, 25 and 26, 1913

Volume XXI

EDITED BY

GARDNER C. ANTHONY WILLIAM T. MAGRUDER

HENRY H. NORRIS

ITHACA, N. Y.

OFFICE OF THE SECRETARY

1914

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	Teachers	Non-Teachers
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Architecture	9	7
Deans and Directors only	—	34
Deans and Directors also holding professorships	80	—
Drawing	52	1
Engineering:		
Agricultural	6	2
Ceramic	1	1
Chemical	6	6
Civil	163	59
Electrical	153	62
Experimental	11	0
Gas	12	7
General	12	28
Highway	20	9
Hydraulic	37	25
Industrial and Efficiency	12	13
Irrigation	0	6
Marine	1	0
Mechanical	153	39
Mining	23	1
Municipal, State and Sanitary	17	11
Publicity	—	2
Railway	27	13
Steam	27	10
Structural and Bridge	37	28
Topographic and Geodetic	4	1
English and other Languages	8	0
History and Economics	2	3
Journalists, Librarians and Publishers	—	23
Machine Design	39	6
Manual Training	9	—
Mathematics	91	0
Mechanics and Materials	69	4
Officers of National Societies	—	12
Petrography and Mining Geology	0	1

Presidents and other Officers of Educational and Allied Institutions	—	42
Science:		
Chemistry	15	3
Geology	7	4
Metallurgy	12	0
Physics	57	3
Shops and Mechanic Arts	40	1
Trustees of Educational Institutions	—	11
Various other Occupations	—	17

GEOGRAPHICAL SUMMARY OF INDIVIDUAL MEMBERSHIP.

Alabama	15	Mississippi	9	Virginia	11
Arizona	2	Missouri	37	Washington	20
Arkansas	7	Montana	6	West Virginia	7
California	28	Nebraska	13	Wisconsin	31
Colorado	26	Nevada	3	Wyoming	4
Connecticut	24	New Hampshire	7	Australia	4
Delaware	4	New Jersey	36	Belgium	1
Dist. of Columbia	10	New Mexico	4	Brazil	3
Florida	6	New York	175	Canada	30
Georgia	3	North Carolina	9	Chile	3
Idaho	8	North Dakota	9	China	2
Illinois	95	Ohio	74	Cuba	1
Indiana	29	Oklahoma	9	England	2
Iowa	31	Oregon	10	Germany	1
Kansas	20	Pennsylvania	146	Greece	1
Kentucky	4	Rhode Island	12	Hawaii Territory	1
Louisiana	9	South Carolina	8	Hungary	1
Maine	9	South Dakota	7	India	4
Maryland	7	Tennessee	7	Japan	3
Massachusetts	122	Texas	16	Mexico	1
Michigan	47	Utah	10	Panama	2
Minnesota	35	Vermont	8	Turkey	2
				Total	1291

INSTITUTIONS REPRESENTED.

	Members 1911	1912	1913
Acadia University, Wolfville, Nova Scotia	1	1	0
Alabama Polytechnic Institute, Auburn, Ala.	7	8	8
Alabama, University of, University, Ala.	5	3	5
Alberta, University of, Edmonton South, Alta, Canada	0	1	1
Alexander Hamilton Institute, New York, N. Y.	0	0	1
Arizona, University of, Tucson, Ariz.	1	1	2
Arkansas, University of, Fayetteville, Ark.	6	4	5
Armour Institute of Technology, Chicago, Ill.	6	5	5
Boston Industrial School for Boys, Boston, Mass.	0	2	2
Bradley Polytechnic Institute, Peoria, Ill.	2	2	2
Brooklyn Manual Training H. S., Brooklyn, N. Y.	1	1	1
Brooklyn Polytechnic Institute, Brooklyn, N. Y.	7	7	7
Brown University, Providence, R. I.	7	9	9
Bucknell University, Lewisburg, Pa.	2	2	2
Buffalo Technical H. S., Buffalo, N. Y.	1	1	1
California, University of, Berkeley, Cal.	5	6	7
Carnegie Institution, Washington, D. C.	2	1	1
Carnegie Institute of Technology, Pittsburgh, Pa.	13	13	11
Case School of Applied Science, Cleveland, O.	17	14	17
Chestnut Hill Academy, Chestnut Hill, Pa.	1	1	1
Chicago, University of, Chicago, Ill.	2	2	2
Christian Brothers College, St. Louis, Mo.	1	1	2
Cincinnati, University of, Cincinnati, O.	6	6	8
Citadel, The, Charleston, S. C.	1	2	2
Clark College, Worcester, Mass.	2	2	2
Clarkson School of Technology, Potsdam, N. Y.	4	4	4
Clemson A. & M. College, Clemson College, S. C.	1	4	6
Cleveland Technical H. S., Cleveland, O.	1	2	3
College of the City of N. Y., New York, N. Y.	0	1	1
Colorado College, Colorado Springs, Colo.	2	2	2
Colorado School of Mines, Golden, Colo.	1	1	1
Colorado State Agri. College, Fort Collins, Colo.	4	5	5
Colorado, University of, Boulder, Colo.	5	9	13
Columbia University, New York, N. Y.	13	15	16
Cooper Union, New York, N. Y.	6	7	6
Cornell College, Mt. Vernon, Ia.	2	2	2
Cornell University, Ithaca, N. Y.	29	29	27
Cumberland University, Lebanon, Tenn.	1	1	1
Dartmouth College, Hanover, N. H.	4	5	5

	1911	1912	1913
David Rankin Jr. Sch., St. Louis, Mo.	0	1	2
Delaware College, Newark, Del.	3	4	3
Denver, University of, Denver, Colo.	0	1	1
Dickinson H. S., Jersey City, N. J.	0	1	3
Dorchester H. S., Dorchester Center, Mass.	1	1	1
Drexel Institute, Philadelphia, Pa.	4	4	9
Duval High School, Jacksonville, Fla.	0	0	1
Escola de Engenharia, Porto Alegre, Brazil	1	1	1
Florida, University of, Gainesville, Fla.	4	3	5
Franklin Institute, Philadelphia, Pa.	1	1	1
Franklin Union, Boston, Mass.	2	4	5
George Washington University, Washington, D. C.	2	2	2
Georgia School of Technology, Atlanta, Ga.	1	1	1
Girard College, Philadelphia, Pa.	0	0	1
Göttingen, University of, Göttingen, Germany	0	0	1
Harvard University, Cambridge, Mass.	15	14	15
Haverford College, Haverford, Pa.	1	1	1
Hebrew Technical Institute, New York, N. Y.	0	0	1
Highland Park College, Des Moines, Ia.	0	0	4
Idaho, University of, Moscow, Ida.	5	6	7
Illinois, University of, Urbana, Ill.	42	51	50
Indiana University, Bloomington, Ind.	0	1	1
Instituto Technico Professional, Porto Alegre, Brazil	1	1	2
International Correspondence Schools, Scranton, Pa.	2	4	5
Iowa State College, Ames, Ia.	13	15	17
Iowa, State University of, Iowa City, Ia.	7	7	7
James Millikin University, Decatur, Ill.	0	0	1
Johns Hopkins University, Baltimore, Md.	0	1	4
Kansas City M. T. H. S., Kansas City, Mo.	1	1	1
Kansas State Agri. College, Manhattan, Kans.	8	12	11
Kansas, University of, Lawrence, Kans.	9	9	7
Kentucky, State University of, Lexington, Ky.	4	4	4
Lafayette College, Easton, Pa.	1	1	4
Lehigh University, South Bethlehem, Pa.	14	16	14
Leland Stanford Jr. Univ., Stanford Univ., Calif.	5	5	3
Lewis Institute, Chicago, Ill.	3	3	3
Louisiana Industrial Institute, Ruston, La.	0	0	2
Louisiana State University, Baton Rouge, La.	3	3	3
McGill University, Montreal, Canada	3	3	5
McKinley High School, St. Louis, Mo.	1	1	1
McKinley M. T. S., Washington, D. C.	0	0	1
Maine, University of, Orono, Me.	6	9	9
Manitoba, University of, Winnipeg, Man.	2	3	3
Marquette University, Milwaukee, Wis.	1	1	1
Massachusetts Agri. College, Amherst, Mass.	1	1	1

	1911	1912	1913
Massachusetts Inst. of Tech., Boston, Mass.	31	38	38
Mechanics Institute, Rochester, N. Y.	0	0	1
Michigan Agri. College, East Lansing, Mich.	19	17	10
Michigan College of Mines, Houghton, Mich.	7	7	8
Michigan, University of, Ann Arbor, Mich.	11	11	20
Milwaukee Public Schools, Milwaukee, Wis.	0	1	1
Minnesota, University of, Minneapolis, Minn.	28	30	31
Mississippi A. & M. College, Agricultural College, Miss.	4	4	8
Mississippi, University of, University, Miss.	1	1	1
Missouri School of Mines, Rolla, Mo.	3	2	2
Missouri, University of, Columbia, Mo	11	11	14
Montana Agri. College, Bozeman, Mont.	2	4	5
Montana, University of, Missoula, Mont.	2	2	1
Nebraska, University of, Lincoln, Nebr.	11	12	13
Nevada, University of, Reno, Nev.	1	1	3
Newark Manual Training H. S., Newark, N. J.	0	1	1
New Hampshire College, Durham, N. H.	2	1	2
New Mexico Coll. of A. & M. Arts, State College, N. M.	4	4	3
New York Evening High School for Men, New York, N. Y.	0	0	1
New York University, New York, N. Y.	4	6	7
North Carolina Agri. College, West Raleigh, N. C.	3	4	4
North Carolina, University of, Chapel Hill, N. C.	2	3	5
North Dakota Agri. College, Agricultural College, N. D.	2	2	2
North Dakota State Science School, Wahpeton, N. D.	0	0	1
North Dakota, University of, University, N. D.	4	4	5
Northwestern University, Evanston, Ill.	4	5	6
Norwich University, Northfield, Vt.	0	0	1
Nova Scotia Technical College, Halifax, N. S.	3	4	2
Ohio Northern University, Ada, O.	2	3	2
Ohio State University, Columbus, O.	23	23	29
Oklahoma A. & M. College, Stillwater, Okla.	1	3	4
Oklahoma, University of, Norman, Okla.	0	4	4
Oregon Agri. College, Corvallis, Ore.	3	4	5
Oregon, University of, Eugene, Ore.	3	3	3
Pasadena High School, Pasadena, Calif.	1	1	1
Pennsylvania College, Gettysburg, Pa.	1	1	1
Pennsylvania Military College, Chester, Pa	0	0	2
Pennsylvania State College, State College, Pa.	14	16	19
Pennsylvania, University of, Philadelphia, Pa.	7	22	26
Pittsburgh Central H. S., Pittsburgh, Pa.	1	1	1
Pittsburgh, University of, Pittsburgh, Pa.	6	8	10
Polytechnic School of Engineering, Regents' St., London	0	1	1
Pomona College, Claremont, Calif.	1	1	1
Pratt Institute, Brooklyn, N. Y.	14	8	7
Princeton University, Princeton, N. J.	2	2	3

	1911	1912	1913
Purdue University, LaFayette, Ind.	17	20	20
Queensland, University of, Brisbane, Australia	1	2	2
Redlands, University of, Redlands, Calif.	0	1	1
Reed College, Portland, Ore.	0	1	1
Rensselaer Polytechnic Institute, Troy, N. Y.	3	5	8
Rhode Island State College, Kingston, R. I.	1	2	2
Robert College, Constantinople, Turkey	0	1	2
Rose Polytechnic Institute, Terre Haute, Ind.	3	3	4
Rutgers College, New Brunswick, N. J.	6	7	6
Santa Clara, University of, Santa Clara, Calif.	0	1	1
Sheffield, University of, Sheffield, England	1	1	1
Southern California University, Los Angeles, Calif.	2	1	1
South Dakota State College, Brookings, S. D.	4	4	6
South Dakota, University of, Vermilion, S. D.	2	1	1
St. Johns University, Shanghai, China	0	0	1
Stevens Institute of Technology, Hoboken, N. J.	12	13	14
Swarthmore College, Swarthmore, Pa.	1	1	2
Sydney, University of, Sydney, Australia	1	1	1
Syracuse University, Syracuse, N. Y.	2	4	8
Technical High School, Edmonton, Alberta, Canada	0	0	1
Tennessee, University of, Knoxville, Tenn.	2	2	3
Texas A. & M. College, College Station, Tex.	8	10	9
Texas, University of, Austin, Tex.	3	4	4
Throop College of Technology, Pasadena, Calif.	2	5	8
Tokyo Imperial University, Tokyo, Japan	1	1	1
Tome Institute, Port Deposit, Md.	0	0	1
Toronto, University of, Toronto, Canada	6	8	10
Tufts College, Tufts College, Mass.	10	14	12
Tulane University, New Orleans, La.	3	3	3
Union University, Schenectady, N. Y.	6	6	7
Universidad de Chile, Santiago, Chile	0	0	3
Utah, University of, Salt Lake City, Utah	9	8	6
Valparaiso University, Valparaiso, Ind.	1	1	1
Vanderbilt University, Nashville, Tenn.	1	1	1
Vermont, University of, Burlington, Vt.	6	7	8
Virginia Military Institute, Lexington, Va.	2	3	3
Virginia Polytechnic Institute, Blacksburg, Va.	5	4	4
Washington & Lee University, Lexington, Va.	1	1	1
Washington State College, Pullman, Wash.	1	1	1
Washington University, St. Louis, Mo.	9	8	6
Washington, University of, Seattle, Wash.	8	13	13
Wentworth Institute, Boston, Mass.	2	9	12
West Philadelphia H. S. for Boys, Philadelphia, Pa.	1	1	1
West Virginia University, Morgantown, W. Va.	5	7	7
Whitman College, Walla Walla, Wash.	3	4	3

	1911	1912	1913
Williamson Free School, Williamson School, Pa.	2	2	2
Wisconsin, University of, Madison, Wis.	27	28	26
Worcester Polytechnic Institute, Worcester, Mass.........	11	13	15
Worcester Trade School, Worcester, Mass.	0	1	1
Wyoming, University of, Laramie, Wyo.	2	3	4
Yale University, New Haven, Conn.	14	23	23

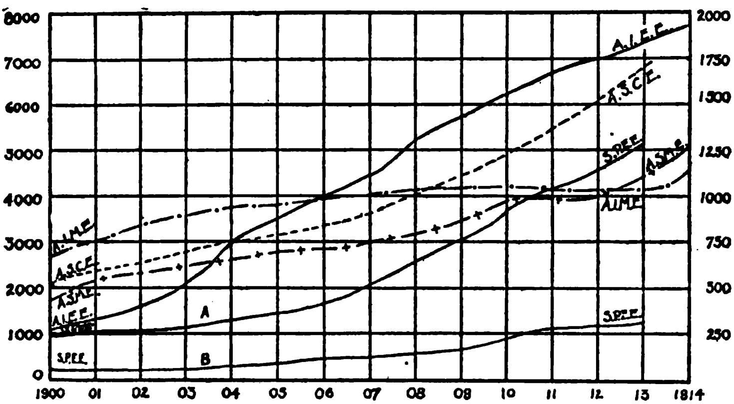
GENERAL SUMMARY.

Different Institutions Represented.

Colleges and Universities teaching Engineering	Members at end of 1911	1912	1913
Domestic	128	135	140
Foreign	12	14	16
Manual Training, High, Correspondence, and Trade Schools	16	18	25
Total Institutions	156	167	181

Members.

Institutional members			45
Teachers, and, in many cases, also practitioners ...	787	850	1024
Non-teachers	253	316	267
	1040	1166	1291



Growth of National Societies.

S. P. E. E. Membership shown to two scales.

A—to show relative rates of growth, right-hand scale.

B—to show relative magnitudes of growth, left-hand scale.

CONSTITUTION*

OF THE

Society for the Promotion of Engineering Education

1. NAME—This organization shall be called the SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION.

2. MEMBERS—*Membership in the Society shall be of two general classes, Institutional and Individual.*

Institutional members shall be educational institutions giving instruction in engineering and scientific subjects.

Individual membership shall be of two classes, Active and Honorary. It shall comprise those persons who occupy or have occupied responsible positions in the work of engineering instruction, together with engineering practitioners and other persons interested in engineering education.

Honorary Members of the Society shall be such persons as may be recommended by unanimous vote of the Council after a letter ballot. In taking this ballot, the Secretary is directed to close the polls one month after the names of the candidates are sent out. Councilors not heard from will be counted in favor of the candidate. Honorary Members shall not have the right to vote, shall not be eligible to office, and shall not be required to pay any fees or dues.

Any *individual* member not in arrears for dues may become a Life Member by paying Fifty Dollars into the treasury of the Society at one time.

The name of each candidate for *individual* membership shall be proposed in writing to the Council by two members by whom he is personally known. *In the case of a candidate for Institutional membership the name shall be proposed by any member familiar with the work of the institution on receipt of an application signed by a responsible officer thereof.* Such name, if approved by the Council, shall be voted on by the Society at the annual meeting, a vote of three-fourths of those present being required to elect; or, during the period between annual meetings, an affirmative letter ballot of three-fourths of those members of the Council whose vote reaches the Secretary within one month from the time

* The words italicized are additions to the constitution and by-laws as recommended by the Minneapolis meeting. They are subject to ratification at the Princeton meeting.

of sending out the name of the candidate shall elect. Such letter ballot elections shall be credited to the previous annual meeting and dues shall date from that time, *except that elections to membership occurring after February 1 shall be credited to the next annual meeting and the dues for the remainder of the year shall be one-half the annual dues.*

3. Officers—There shall be a President, two Vice-Presidents, a Secretary and a Treasurer, each to hold office for one year, or until their successors have been elected and have qualified. The Officers shall be elected by ballot of the Society at the annual meeting.

4. Council—The Council of the Society shall consist of twenty-one elective members, one-third of whom shall retire annually. The Officers and the Past Presidents of the Society shall be members of the Council *ex-officio.*

Any member of the Society shall be eligible to election to the Council, provided that not more than one elective member shall be from any one college.

Members of the Council shall be elected by ballot by the Society at its annual meeting.

The Council shall constitute a general executive body of the Society, pass on proposals for membership, elect candidates *ad interim,* attend to all business of the Society, receive and report on propositions for amendments to the constitution, and shall have power to fill temporary vacancies in the offices.

The President of the Society shall be Chairman of the Council, and the Secretary of the Society shall be Secretary of the Council and shall keep the minutes of its meetings and an accurate record of all its actions.

When votes taken by letter ballot of the Council shall be required, all votes which reach the Secretary within one month from the time of sending out the ballots shall be counted, but votes reaching the Secretary later than the time here specified shall not be counted.

5. Nominating Committee—The Nominating Committee shall consist of the Past Presidents and the seven elective members of the Council retiring the following year, provided, however, that if, of this committee, the number in attendance at any meeting be less than five, the President shall make appointments so as to form a committee of five.

6. Fees and Dues—The admission fee *for an individual, active member,* which shall also include the first year's dues, shall be Four Dollars ($4.00), and the annual dues, which shall include the subscription price of the Bulletin, provided for in Art. 8, shall be Four Dollars ($4.00), payable at the time of the annual meeting.

The admission fee for institutional members, which shall also include the first year's dues, shall be Ten Dollars ($10.00), and the annual dues, which shall include the subscription price of three copies of the Bulletin,

and of the PROCEEDINGS, *provided for in Art. 8, shall be Ten Dollars ($10.00), payable at the time of the annual meeting.*

The fiscal year shall end with the close (or adjournment) of the annual meeting. Those in arrears more than one year shall not be entitled to vote, nor to receive copies of the PROCEEDINGS, and such members shall be notified thereof by the Secretary one month previous to the annual meeting. Any member who has been in arrears more than two years and duly notified by the Secretary, shall be dropped from the roll, until such arrearages are paid.

7. MEETINGS—There shall be an annual meeting at such time and place as the Society at the preceding annual meeting, or the Council may determine.

8. PUBLICATIONS—The publications of the Society shall include an annual volume of PROCEEDINGS, to be published and distributed to the membership as soon as possible after the annual meeting; and a monthly BULLETIN, to be published from September to June, inclusive.

9. AMENDMENTS—This Constitution may be amended by a two-thirds vote of those present at any regular meeting of the Society provided the amendment shall have been approved by the Council by letter ballot by a two-thirds vote of the members voting.

BY-LAWS OF THE SOCIETY AND RULES GOVERNING THE COUNCIL.

First. The Officers of the Society shall constitute a Committee to arrange for the annual meeting and to prepare a program for the same.

Second. The President, the Secretary and the Treasurer shall constitute an Executive Committee which shall have charge of all matters relating to the expenditure of money of the Society, the making of appropriations to Committees and for other purposes, the making of contracts, the approval of bills, and also during the period between the meetings of the Council shall have charge of other business affairs of the Society.

Third. Expenditures of money may be made only in accordance with a definite appropriation or by direct vote of the Executive Committee.

Fourth. Reading of papers shall be limited to fifteen minutes each or to such other time as may be designated by the Program Committee, and abstracts of papers of about three hundred words shall be printed when practicable, and distributed in advance to the members.

Fifth. The time occupied by each person in the discussion of any paper shall not exceed five minutes.

Sixth. The President, the Secretary and the retiring Secretary shall constitute a Publication Committee, of which the Secretary shall be

Chairman, to edit and have charge of the publication of the monthly BULLETIN and the PROCEEDINGS of the Society, except the volume of Proceedings of the last convention, which shall be edited by the retiring Secretary. If at any time there be no retiring Secretary the retiring President shall be a member of this Committee.

Seventh. The Officers, members of the Council and members of the local Convention Committee shall constitute a Committee on Sociability to introduce members and guests to each other at the annual meetings and in general to promote a spirit of good fellowship.

Eighth. The subscription price of the BULLETIN shall be One Dollar per year, payable in advance.

Ninth. Additions or amendments may be made to these By-Laws at any regular meeting of the Society, on the recommendation of the Council by a two-thirds affirmative vote of the Council and of the Society.

PUBLICATIONS.

The publications of the Society can be obtained from the Secretary. The current issues are distributed gratuitously to members in good standing, *one copy of each to each individual member and three to each institutional member.* The price of the bound volumes of the PROCEEDINGS of former years is $2.50 to non-members, $2.00 to public libraries, and $1.50 to members for their own libraries.

The BULLETIN is issued monthly from September to June. The price to non-members is $1.00 per year. Libraries may order the BULLETIN and the PROCEEDINGS at $3.00 per year.

Reprints of papers may be ordered when the papers are in type form, and either with or without covers, at a price depending upon the number of pages and copies desired.

MINUTES OF THE TWENTY-FIRST ANNUAL MEETING.

MINNEAPOLIS, MINN.

JUNE 24 TO JUNE 26, 1913.

The twenty-first annual meeting of the Society for the Promotion of Engineering Education was held in Minneapolis, Minn., June 24 to 26, 1913. The sessions were held in the new Engineering Building of the University of Minnesota. Registration headquarters were at the Hotel Leamington. The program included a joint session with the American Water Works Association at the West Hotel.

TUESDAY, JUNE 24.

Morning Session.

The meeting was called to order by President Wm. T. Magruder, Professor of Mechanical Engineering, The Ohio State University, at 9:45 a. m. Dean F. C. Shenehon was introduced and delivered on behalf of the University and of President Geo. E. Vincent a brief address of welcome including the reading of a letter from President Vincent. President Magruder responded expressing gratitude on the Society's behalf for the cordial welcome extended to the visiting members.

The Secretary, Professor H. H. Norris, and the Treasurer, Mr. Wm. O. Wiley, presented their reports which were on motion accepted. Mr. Wiley had distributed mimeographed

copies of the essential parts of his report and explained verbally that the finances of the Society are in satisfactory condition, even better, in fact, than a year ago. At his request, on motion, the Society instructed the President to appoint an auditing committee to examine the accounts and report at a later session of the meeting. The President appointed Professors G. R. Chatburn, F. A. Fish and O. A. Leutwiler.

After calling for reports from standing committees, none of which were prepared to report, the President requested Dean Bishop to present the report of the Committee on College Administration which had been printed in preliminary form in the June BULLETIN. After Dean Bishop's introduction of the report, he and the Secretary were appointed, on motion, a special convention committee to recommend changes in the By-laws to provide for institutional membership which had been separately recommended in the report and by the Secretary. The topics treated in the report were then fully discussed. The feature which aroused the greatest interest was the real or apparent falling off in the registration in engineering schools and the reasons therefor.

In the absence of Director H. S. Person, of the Amos Tuck School, of Dartmouth College, his paper on "Academic Efficiency" was read in full by the Secretary. Professor A. E. Haynes followed with a short paper entitled "A Source of Academic Inefficiency." In the discussion which this opened, the famous definition of a university as "a log with Mark Hopkins on one end and a boy on the other" became the focus of a lively controversy. Among the speakers was President A. Ross Hill of the University of Missouri.

After the discussion 95 persons were elected to membership in the Society on recommendation of the Council.

Afternoon Session.

The session was called to order at 2:00 p. m. by President Magruder who introduced Professor C. Russ Richards, who read his paper on "Ideals of College Laboratory Construction," illustrating it by means of the lantern. In Professor

Schmidt's absence Professor Richards also read the illustrated paper entitled "Additions to the Equipment of the Railway Engineering Department of the University of Illinois" which had been printed in the June BULLETIN. The two papers were discussed together and Dean W. F. M. Goss, under whose direction the recent building work at the University of Illinois has been carried out, was subjected to quite a cross-examination as to details of the reasons for certain things. Principal A. L. Williston of the Wentworth Institute read his paper "New Buildings for Wentworth Institute: Arrangement of Laboratories and Equipment" with lantern illustrations. The paper opened up the general subject of industrial education and stimulated a lively discussion. The promised paper by Mr. John R. Freeman on "Studies of Requirements in Engineering College Buildings" was read by title and ordered printed in the *Proceedings* when completed.

In a brief business session following the above discussion the Auditing Committee reported as follows:

"We, your Auditing Committee, have examined the vouchers and the report of the Treasurer, Mr. W. O Wiley, and find them in agreement and correct as to expenditures."

(Signed) O. A. LEUTWILER.
F. A. FISH,
G. R. CHATBURN,

The report was adopted without discussion.

Evening Session.

The evening session was a joint one with the American Water Works Association at West Hotel. An illustrated lecture on "Masonry Dams" by Mr. Edw. Wegman preceded a discussion on Hydraulic Engineering Education. President Dow R. Gwinn, of Terre Haute, Ind., President of the American Water Works Association, presided. Two papers formed the basis for discussion, one entitled "Hydraulic Engineering Education," by Professor D. W. Mead, the other on "Undergraduate Training for Hydraulic Engineers," by Professor O. L. Waller. Discussion which followed showed the interest

of practical engineers in the fundamental principles of engineering education. The discussion was contributed by Mr. J. W. Ledoux, Chief Engineer of the American Pipe and Construction Co., Mr. John C. Trautwine, Jr., Professors R. L. Sackett and W. T. Magruder, and Mr. John W. Alvord, Past-President of the American Water Works Association.

WEDNESDAY, JUNE 25.

Morning Session.

President Magruder called the session to order at 9:30 a. m. and stated that no report from the Joint Committee on Engineering Education would be presented as its investigation had been referred to the Carnegie Foundation for the Advancement of Teaching.

President A. C. Humphreys's paper on "Four vs. Five or More Years of Engineering Education," was read by Dean W. G. Raymond who, by permission of the chair, interspersed his own comments with the reading. Professor Swain's paper on the same subject which, with President Humphreys', had appeared in the May BULLETIN was read by title. Professor F. H. Constant contributed a paper entitled "The Five-Year Course of the University of Minnesota," which was illustrated with several charts. The general topic of the morning was then fully discussed, Professor Constant being called upon for the closure.

Professor A. L. Hyde next read his paper on "The System of Grading Students Used at the University of Missouri." At the suggestion of Dean C. M. Woodward, who took the chair for the balance of the session, the remaining paper that morning was presented by the Secretary in the absence of the author, Mr. D. M. Wright. This was entitled "The Revision and Standardization of English Technical Terms." As the paper had been printed in the June BULLETIN, a summary was given with some explanation of the reason for the paper. Mr. Wright's resolution recommending the appointment by the

Society of a committee to consider and promulgate the use of technical nomenclature was read and recommended by the chairman for discussion. The papers of Professor Hyde and Mr. Wright were then fully discussed. President Magruder returned to the chair to put the following resolution, which had been prepared in the meantime by Professor J. J. Flather. "Inasmuch as there is a decided need for the promotion and use of a preferred nomenclature, therefore be it resolved that the Society for the Promotion of Engineering Education appoint a committee to report to the Society any recommendations that they may deem proper to effect an improvement in technical nomenclature." This resolution was adopted without discussion.

Afternoon Session.

The afternoon session was divided into two sections meeting simultaneously at 2:00 p.m. in different rooms of the Engineering Building.

The program for Section 1, presented under the chairmanship of President Magruder, comprised three papers. One of these, a "Symposium on the Coöperative System of Education from the Employer's Point of View," by Dean Herman Schneider, was read by title at Dean Schneider's request. A paper, "Engineering College Shop Practice," by Professor J. V. Martenis and Mr. W. H. Richards, was read and illustrated with elaborate exhibits of shop products. Professor Martenis read the text of the paper and Mr. Richards demonstrated the equipment. This paper elicited a very lively discussion, the authors being subjected to a quiz for a considerable time. Professor T. E. French presented his paper on "The Educational Side of Engineering Drawing," which also brought out an interesting discussion.

The program of Section 2 was made up of the following papers on Highway Engineering Education which had been solicited by Professor A. H. Blanchard. On account of Professor Blanchard's absence due to his attending the International Road Congress in London, Dean F. E. Turneaure presided. The following papers were read mostly by members

of the Society in the absence of the authors: "Highway Engineering, An Essential of Civil Engineering Curricula," by Professor A. H. Blanchard; "Prospective Opportunities for Highway Engineers in a National Highway Department," by Mr. Charles Henry Davis; "Opportunities for Highway Engineers in State Departments," by Mr. A. N. Johnson; "Opportunities for Highway Engineers in Municipal Departments," by Mr. Geo. W. Tillson; "Opportunities for Highway Engineers in Contractors' Organizations," by Mr. H. B. Pullar; "Opportunities for Highway Engineers in Manufacturing Companies," by Mr. Wm. H. Kershaw; "Opportunities of Highway Engineers in the Southern States," by Professor R. J. Potts; "Essential Qualifications of Highway Engineers," by Mr. Harold Parker; "Short Winter Courses in Highway Engineering," by Professor C. E. Sherman; "The Human Element in the Education of Highway Engineers," by Dr. E. Stagg Whitin; "Essentials of Earth and Gravel Road Construction in Highway Engineering Courses," by Professor I. O. Baker; "Soils, An Essential of Courses in Geology for Civil Engineers," by Mr. Geo. W. Cooley; "Financial Problems in Highway Engineering, An Essential Part of Courses in Economics," by Professor G. R. Chatburn; "Highway Materials Laboratory Work in the Civil Engineering Course," by Professor F. H. Eno; "Chemistry of Bituminous Materials in the Civil Engineering Course," by Mr. Prevost Hubbard, and "Highway Surveys in the Civil Engineering Course," by Mr. Henry B. Drowne.

The papers were discussed as a whole and emphasis was laid upon the fundamental principles of highway engineering education. The general sentiment tended to show that the fundamental principles of this subject should be taught to all civil engineers and that the tendency to teach highly-specialized courses, due to momentary pressure from the field, should be resisted.

Evening Session.

The annual address of the President, entitled "The Good Engineering Teacher, His Personality and Training," was

delivered immediately after the annual dinner which was held at the Leamington Hotel. On account of the high temperature and humidity of the atmosphere, the address was not discussed.

THURSDAY, JUNE 26.

Morning Session.

In opening the convention at 9:30 a. m., President Magruder introduced Mr. Ivy L. Lee, executive assistant, The Pennsylvania R. R. Co., who read his paper entitled "How Can the College and the Industries Coöperate?" The promised paper by Mr. E. D. Sabine, first assistant engineer of the New York Central R. R. Co., was not in hand and was read by title. Mr. Lee's paper struck a responsive chord in the minds of the members present and the subject of the qualifications of a technical graduate was vigorously discussed.

Two papers, "The Units of Force," by Professor E. V. Huntington, and "Uniformity of Notation in Strength of Materials," by Professor I. P. Church, were presented, the first by Professor E. R. Hedrick and the second by Professor J. J. Flather. The latter explained that Professor Church preferred to have his paper considered a contribution to the discussion of the other. The general subject of teaching mechanics, especially dynamics, proved intensely interesting to the membership and resulted in a resolution by Professor J. E. Boyd that a special Committee on the Teaching of Mechanics to Engineering Students be appointed and that the subject of teaching dynamics be referred to it. This resolution was adopted and President Magruder announced the following appointments: Professor E. R. Maurer, Chairman, Professors L. M. Hoskins, S. M. Woodward, L. A. Martin, Jr., C. E. Fuller and H. F. Moore, Mr. A. Kingsbury, Dr. Wm. Kent and Dr. S. A. Moss.

On motion, Professor I. P. Church's paper with its recommendations was referred to the new committee.

The President announced (1) the appointment of Dean G. C. Anthony and Professor A. N. Talbot on the Joint Committee on Engineering Education to take the places of President A. C. Humphreys and Professor Samuel Sheldon who had been appointed to represent other societies on this committee; (2) the appointment of the following Committee on Statistics: Professor A. J. Wood, Chairman, Professors F. A. Barnes, F. A. Fish, H. H. Stoek and J. D. Phillips; (3) The recommendation of the Council that a Committee on Teaching Physics to Engineering Students be appointed and that he accordingly had selected the following: Professor D. C. Miller, Chairman, Professors G. V. Wendell, J. M. Jameson, W. S. Franklin, H. M. Raymond, O. M. Stewart, E. P. Hyde, G. A. Goodenough and F. K. Richtmyer.

He also stated that the Committee on College Administration had been continued for another year by the action of the Council.

The Committee on Resolutions then reported as follows:

"The visit of the Society for the Promotion of Engineering Education to Minneapolis has been made pleasant to its members by the many courtesies extended, and your committee desires to record its appreciation.

Therefore, be it Resolved: That the thanks of the Society be hereby tendered to President Vincent, Dean Shenehon, and the other members of the Faculty of the University of Minnesota, and to the local committee for providing places of meeting, and for the various entertainments offered, to the citizens of Minneapolis who furnished automobiles for the delightful ride about the city and who have otherwise assisted in our entertainment, and to the ladies who have acted as hostesses to the ladies accompanying our members.

Further be it Resolved: That the thanks of the Society be tendered to the President and members of the University Club and to the President and members of the Lafayette Country Club for the privileges extended to our members, to

the Walker Art Gallery and to the Washburn-Crosby Co., which has thrown open its works to us.

(Signed) W. O. WILEY,
M. S. KETCHUM,
F. L. BISHOP."

On motion of Professor A. E. Haynes, a vote of thanks was tendered the Secretary for his work on behalf of the Society.

The Nominating Committee recommended the following persons as officers for the next year. On motion they were duly elected by the Society.

For President, G. C. Anthony, of Tufts College.

For Vice-President, H. S. Jacoby, of Cornell University.

For Vice-President, D. C. Humphreys, of Washington and Lee University.

For Members of the Council: H. W. Tyler, of the Massachusetts Institute of Technology; J. F. Hayford, of Northwestern University; A. S. Langsdorf, of Washington University; S. M. Woodward, of State University of Iowa; M. S. Ketchum, of University of Colorado; F. P. Spalding, of University of Missouri; P. F. Walker, of University of Kansas.

For Secretary, H. H. Norris, of Ithaca, N. Y.

For Treasurer, W. O. Wiley, of New York City.

The above committee comprised the following: H. T. Eddy, Chairman, C. M. Woodward, W. G. Raymond, F. E. Turneaure C. H. Crouch, C. L. Crandall and J. E. Boyd. J. E. Boyd acted as Secretary.

The Society approved the action of the Council providing for such a change in the By-laws as will prescribe a committee on sociability to consist of the officers of the Society and the local committee at each meeting.

President Magruder announced the following appointments on the Committee on the Standardization of Technical Nomenclature: Professor J. J. Flather, Chairman, Mr. D. M. Wright, Professors W. D. Ennis, S. C. Earle and F. N. Raymond.

Afternoon Session.

At the 2:00 o'clock session, over which President Magruder presided, reports were read from the four committees on improvement in engineering instruction. These reports had been prepared under the direction of the respective chairmen as follows: Civil Engineering, Professor F. P. McKibben; Electrical Engineering, Professor C. F. Scott; Mechanical Engineering, Professor A. M. Greene, Jr.; and Mining Engineering, Professor F. W. Sperr.

On motion by the Society, these four committees were continued for another year with the request that they carry out their own programs and publish in the BULLETIN at once something tangible in the way of suggestions.

Professor H. Wade Hibbard then read his paper on "Thesis Directions for Students" as an appendix to which a list of some 1,500 thesis topics was presented but not read. The subject of thesis work aroused considerable discussion and in the main Professor Hibbard's contention for the place of the thesis in the curriculum was supported.

Professor Magruder read the paper by Professors C. E. Sherman and R. K. Schlafly entitled "Summer Surveying Courses at The Ohio State University," which had been printed in extended abstract in the June BULLETIN. The balance of the session was spent in the discussion of this paper, after which the convention adjourned for a trip on Lake Minnetonka and a closing dinner at the Lafayette Country Club.

ATTENDANCE AT THE CONVENTION.

One hundred and seventeen members and guests registered at the convention, a very satisfactory number in view of the conflicts with other Society meetings and the fact that the meeting was held farther west than any preceding one.

The names registered are as follows: L. K. Adkins, Ethan Allen, Emil Anderson, M. N. Baker, A. T. Baldwin, Frederic Bass, J. T. Bates, S. W. Beyer, F. L. Bishop, James E. Boyd, B. B. Brackett, W. E. Brooke, S. S. Bruce, F. E. Burpee, E.

F. Chandler, G. R. Chatburn, H. E. Cobb, E. F. Coddington, E. H. Comstock, F. H. Constant, Robertson Cook, C. L. Crandall, Mrs. Crandall, C. H. Crouch, A. S. Cutler, H. H. Dalaker, R. L. Daniel, Fred Dedolph, H. M. Dibert, J. W. Dietz, H. T. Eddy, H. S. Evans, M. I. Evinger, J. H. Felgar, F. A. Fish, J. J. Flather, A. H. Ford, H. C. Ford, M. M. Foss, E. H. Freeman, T. E. French, A. J. Frith, W. F. M. Goss, S. C. Hadden, A. E. Haynes, E. R. Hedrick, H. Wade Hibbard, F. G. Higbee, A. Ross Hill, W. C. Hoad, J. A. Hunter, A. L. Hyde, A. C. Jewett, W. H. Kavanaugh, E. W. Kellogg, Milo S. Ketchum, R. S. King, W. H. Kirchner, Ivy L. Lee, O. A. Leutwiler, E. S. Macgowan, C. E. Magnusson, Mrs. Magnusson, W. T. Magruder, J. V. Martenis, W. H. Martin, C. J. Martinson, E. R. Maurer, D. W. Mead, W. H. Meeker, C. E. Mickey, J. L. Mowry, C. C. Myers, B. L. Newkirk, H. H. Norris, R. W. Otto, Chas. H. Owen, J. I. Parcel, S. M. Pike, Wm. G. Raymond, C. Russ Richards, W. H. Richards, F. B. Rowley, W. B. Russell, W. T. Ryan, Adolph Shane, F. C. Shenehon, G. D. Shepardson, C. F. Shoop, P. A. Small, J. E. Smith, H. C. Solberg, F. P. Spalding, F. W. Sperr, F. W. Springer, G. W. Sublette, L. B. Taylor, C. C. Thomas, Mrs. Thomas, H. A. Thomas, J. S. Thompson, M. E. Todd, F. E. Turneaure, P. F. Walker, O. L. Waller, Chauncey Wernecke, N. S. Whipple, W. O. Wiley, W. S. Williams, A. L. Williston, Mrs. Williston, F. N. Willson, C. M. Woodward, S. M. Woodward, L. F. Wooster, A. S. Young, Anthony Zeleny (117).

Social Features of the Convention.

The social feature of Tuesday afternoon was an automobile trip. The itinerary included a portion of the business and residence districts of the city and about twenty of the thirty-five miles of boulevard belonging to the Minneapolis parkway system. This boulevard skirts a number of beautiful lakes within the city limits and includes the park within which is located the famous Minnehaha Falls. Twenty-four automobiles had been promised for this trip, but, on account of a heavy shower which came up at about the time the party was

to start, only sixteen were available. All who wished to go were accomodated without difficulty, however, as a number of members had left before the trip was scheduled to begin, supposing that it would be given up. The rain only partly interfered with the comfort of the members and not at all with their pleasure.

On Wednesday afternoon the ladies of the faculty tendered a reception to the members of the Society and their guests. This was attended by about one hundred persons. During the reception interesting moving pictures, representing scenes in the Glacier National Park, were exhibited and added to the pleasure given by the other entertainment.

At the annual dinner held on Wednesday evening in the main ball room of the Hotel Leamington there were eighty-one members and guests present. An informal reception was held by President Magruder in the lobby immediately before the dinner, and after the dinner and the President's address, the diners adjourned to the cool and commodious piazzas where social intercourse was enjoyed until a late hour.

After final adjournment on Thursday afternoon the local committee tendered an excursion to Lake Minnetonka. The trip was made by trolley from Minneapolis to Excelsior, at which point the launch "Victor" was boarded for a short sail on Lake Minnetonka ending at the Lafayette Country Club. Here a dinner was served and the guests returned to Minneapolis about 9:00 p. m. Approximately eighty-five persons participated in the excursion.

During the sessions several parties were escorted through the flour mills and the T. B. Walker art galleries.

Meetings of the Council at Minneapolis.

Meetings of the Council were held on June 24, 25 and 26. Members who attended one or more sessions were: F. L. Bishop, J. E. Boyd, G. R. Chatburn, C. L. Crandall, C. H. Crouch, H. T. Eddy, C. E. Magnusson, W. T. Magruder, H. H. Norris, W. G. Raymond, C. Russ Richards, G. D. Shepardson, W. O. Wiley and C. M. Woodward. The meetings were held

in the faculty room adjoining Dean Shenehon's office. They were all scheduled for three quarters of an hour preceding the morning sessions.

The important motions passed were as follows:

1. That the Council approve the general plan of membership by educational institutions.

2. That the institutional membership fee be $10.00, that each institutional member receive three sets of publications and that each be entitled to one official delegate at annual meetings.

3. That parts of the BULLETIN be reprinted as the *Proceedings* of the Society, and that the Publication Committee be authorized to include, as part of such *Proceedings*, papers other than those presented at the annual meeting.

4. That the Executive Committee be requested to present a budget of estimated receipts and expenditures for the coming year.

5. That each member of the incoming Council be furnished with a copy of this budget.

6. That the Committee on Industrial Education be discharged with thanks and that it cease to be a standing committee.

7. That the Committee on Statistics be continued as a standing committee.

8. That the Society coöperate with the Carnegie Foundation for the Advancement of Teaching in its investigations.

9. That the appointment of Messrs. Anthony and Talbot to represent the Society on the Joint Committee on Engineering Education be approved.

10. That the Committee on the Teaching of Mathematics to Students of Engineering be discharged with thanks and that Professor Huntington personally be thanked for his efforts.

11. That the President's plan for Committees on Teaching Mechanics to Engineering Students and Teaching Physics to Engineering Students be approved.

12. That the appointment of delegates to the next National Conservation Congress be referred to the incoming officers.

13. That the incoming Executive Committee be requested to confer with officers of other societies looking to a permanent arrangement for avoiding conflicts and securing consecutive dates for meetings as nearly as possible.

14. That Princeton be recommended to the incoming Council as a place for the 1914 meeting, the date to be arranged in coöperation with the American Society for Testing Materials.

15. That California be approved for the 1915 meeting and that the incoming Council be recommended to proceed at once with suitable arrangements.

16. That a new department to be entitled "Questions and Kinks" be added to the BULLETIN.

17. That a recommendation be laid before the Society to permit such a change in the By-laws as will provide for a Committee on Sociability to serve especially at the annual meeting, and to consist of the officers of the Society and the members of the local committee.

18. That a group photograph of the convention be published in the BULLETIN with key.

19. That abstracts of all papers must be received by the Society at least two weeks before the annual meetings.

20. That the incoming Committee on Publication provide for the publication of a twenty-year index to the *Proceedings.*

21. That members elected after January 1 be granted a reasonable reduction in dues for the balance of the college year.

22. That the Council recommend that the Society take the steps necessary to render the Secretaryship permanent.

23. That the retiring and incoming presidents and the Treasurer be appointed a committee to consider and report to the Council in 1914 as to whether the Secretary of the Society should necessarily be in the active work of teaching, and second, to find a suitable man who will accept the position of permanent Secretary of the Society beginning in 1914.

24. That the Committees on Coöperation in Civil, Mechanical, Electrical and Mining Engineering Education, respect-

ively, and the Committee on College Administration be continued for another year and requested to bring in full and final reports.

In addition to the above motions the President announced appointments to the Committees on Statistics, on the Teaching of Mechanics to Engineering Students and on the Teaching of Physics to Engineering Students as reported in the minutes of the annual meeting.

The following applicants were recommended to the Society for election: M. W. Acker, S. O. Andros, W. R. Appleby, A. T. Baldwin, H. H. Barnes, Jr., H. G. Benedict, A. G. Bierma, J. R. Bloom, J. N. Bridgman, O. P. Briggs, S. S. Bruce, C. J. Carter, A. L. Cook, Paul Cook, Robertson Cook, S. E. Coombs, Ollison Craig, Ray Crow, C. P. Crowe, L. F. Curtis, H. M. Dadourian, R. E. Davis, H. M. Dibert, C. F. Dreyer, F. C. Dyer, W. W. Edwards, Harrington Emerson, C. E. Ferris, A. B. Fletcher, C. W. Foulk, W. A. Gleason, L. M. Gram, W. F. Gurley, George Hatjidakis, W. A. Hedrick, F. W. Hehre, F. A. Hitchcock, E. B. House, Joseph Hudnut, R. W. Hunt, H. B. Hutchins, E. A. Johnson, C. T. Johnston, E. W. Kellogg, W. H. Kershaw, H. W. King, H. H. Lauer, J. N. LeConte, J. F. Lewis, O. L. Lewis, S. B. Lilly, C. M. McKergow, J. H. MacCracken, J. R. Marker, W. H. Martin, F. E. Mathewson, A. F. Meyer, A. R. Munro, C. A. Nash, W. H. Perry, H. S. Philbrick, Anthony Pinto, H. C. Ramsower, H. U. Ransom, W. H. Rayner, B. K. Read, Irwin Rew, Clifford Richardson, H. E. Riggs, J. E. Robertson, F. A. Robbins, J. W. Rollins, J. A. B. Scherer, R. K. Schlafly, E. L. Shepard, S. L. Simmering, P. R. Smith, C. K. Smoley, J. F. Stevens, J. F. Stone, R. L. Streeter, W. W. Strong, B. N. Swamy, W. C. Taylor, W. E. Taylor, R. C. Terrell, H. A. Thomas, C. J. Tilden, M. E. Todd, Alexander von Ritter, E. C. White J. B. Whitehead, E. S. Whitin, W. S. Williams and F. N. Willson. (95).

The following estimated budget of income and expenses for the coming year was reported by the Executive Committee:

Estimated income.

From current and back dues	$4,800
From advertising in BULLETIN	1,100
From publications of all kinds	600
Total	$6,500

Estimated expenses.

Treasurer's office—salaries	$ 250
Treasurer's office sundries	50
Secretary's salary	1,000
Secretary's clerical assistance	300
Secretary's stenographer	400
Sundry printing	200
Printing BULLETIN*	1,500
Mailing BULLETIN	50
Printing *Proceedings*	1,500
Drawing and engraving	100
Expenses, Minneapolis meeting	250
Postage—general	500
Expressage	75
Telegrams	15
Office sundries	50
Total	$6,240
Estimated excess of receipts over expenses	$ 260

Respectfully submitted,
HENRY H. NORRIS,
Secretary.

SECRETARY'S REPORT FOR 1912–1913.

The past year has been an active one in the line of publications and their distribution.

Last year the Society reprinted the report of the Committee on Teaching Mathematics to Engineering Students, binding it in semi-flexible blue covers. This was advertised by means of circulars sent to mathematicians and to others interested, by insertions in the American Mathematical Society *Bulletin*, by reviews in the technical press and by insertions in our own BULLETIN. As a consequence the first edition of 1,000 was soon disposed of and a second edition of 500, incorporating revisions

**Note.*—The above estimate for printing BULLETIN is based on the cost during the past year and no allowance is made for the credit to be allowed on the *Proceedings* which are to form the main part of the BULLETIN. The Publication Committee hopes to save $500 by eliminating double publication.

by the Committee, is now being sold. The income from these sales covered the cost of publication and enabled the Executive Committee to reimburse the committee which prepared the report for their expenditures. The report has taken its place as a standard of reference and its preparation and publication are highly creditable to the Committee and the Society. The Treasurer's report shows that the sales brought in $699.71 during the year.

The Symposium on Efficiency in College Administration and on the Teaching of Scientific Management was published late in the year and is now being advertised. This is a companion volume to the Mathematics Report and it will undoubtedly take its place as a standard of reference also. The edition of this is but 500 copies.

The expedient of printing the *Proceedings* in two parts was adopted this year in order to get the efficiency papers into the hands of the members early. By this means a portion of the *Proceedings* was distributed several months earlier than usual. The second part would have been in the hands of the members before this except for an unusual congestion in the printing office. On account of the complicated nature of the program of the Boston meeting the publication of the *Proceedings* has presented unusual difficulties this year. The Executive Committee felt justified in incurring the extra expense for binding the *Proceedings* in two parts for the reason given.

An unusual effort has been made this year to circulate the reports of committees of the Society. These reports have been advertised in every possible way and a large number have been sent out. The Publication Committee feels that an important part of the work of the Society is the circulation of its findings on important educational matters. A most serious problem is how to place the reports where they will have their maximum influence.

The membership campaign has been carried on this year under various schemes and with fairly satisfactory results. While there is still a field from which to draw new members there is evidently a "saturation point" of membership which we are gradually approaching.. Unless there is some radical change in the scope of the work of the Society, which at present seems inadvisable, the ultimate membership will probably not exceed 2,000. The normal growth seems now to be about 100 members per annum. The best results are secured through personal invitations from the members to their friends. These have been especially effective during the past six weeks. At the Boston meeting 68 persons were elected to membership, which number was increased by 60 during the year, making a total gross increase of 128 for the year. During the year 42 resignations were accepted, 20 members were dropped for non-payment of dues and 3 died. The net increase is smaller than it would have been had we followed the usual custom of sending out letter ballots

up to the close of the year. To offset this there will be a larger number elected at this Minneapolis meeting than usual.

The Treasurer's report shows that the finances of the Society are in satisfactory condition. Supplementing his report I would say that the actual expenses incurred during the year are less than the income. There are bills for printing Part II of Vol. 20 of the *Proceedings* and the April, May and June BULLETINS, which have not yet been presented. This result is satisfactory in view of the extraordinary publication expense to which the Society has been subjected this year, the printing bills actually paid amounting to $4,356.77.

The arrearages for dues are not serious at the present time, only one member owing more than $8.00. 67 members owe for dues prior to 1912–13. An inspection of the list shows that in most cases the arrearage is due to oversight.

The life membership fund has not grown during the past year except by the addition of interest. As the life membership fee is small in proportion to the annual dues, no effort has been made to increase the life membership.

An important element of the Society's work is the relation to other associations. An interesting feature in this connection was the joint session held with the American Road Congress at Atlantic City on October 3, 1912. At this session the following papers were presented under the general direction of Professor F. P. McKibben. The meeting was held on Young's pier, Atlantic City, on the afternoon of October 3 with an attendance of about 150 persons, of whom about 15 to 20 were members of the society.

"Highway Engineering Education," Professor Arthur H. Blanchard of Columbia University, New York City.

"Essential Requisites in the Making of a Highway Engineer," Stuart A. Stephenson, Jr., instructor in civil engineering, Rutgers College, New Brunswick, N. J.

"What Should Constitute a Course in Highway Engineering," Professor E. B. McCormick, professor of experimental engineering, Kansas State Agricultural College, Manhattan, Kans.

"Highway Engineering in a General Course in Civil Engineering," Professor Hugh Miller, professor of civil engineering, Clarkson School of Technology, Potsdam, N. Y.

At the Boston meeting a joint session was held with the American Institute of Electrical Engineers, the proceedings of which appear in the transactions of that society. A copy of the report of the A. I. E. E. Committee on Industrial Education, which was presented at this joint session, was sent to each member of the Society last July. At this Minneapolis meeting a joint session with the American Water Works Association will be held. This feature of the Society's work must have careful attention in the future.

RECOMMENDATIONS.

It would seem wise to have a committee to study the relations of this society to other societies with allied interests. It might be well to have on such a committee one representative of each of the societies with which affiliation is desired.

There is an increasing tendency, I believe, for educational instititions to be represented by official delegates. This suggests the importance of a closer union between the Society and institutions of learning. I suggest that there be introduced some form of institutional membership corresponding to the accompanying membership of the National Electric Light Association, the American Electric Railway Association and other societies. Institutional membership would greatly strengthen this society and it would make the Society more useful to the institutions. Fees for institutional membership might be graduated in accordance with the enrollment, *e. g.*, over 5,000, $25.00; 4,000 to 5,000, $20.00; 3,000 to 4,000, $15.00; 1,500 to 3,000, $10.00; under 1,500, $5.00.

We now publish a great deal of material in duplicate in the BULLETIN and *Proceedings*. While there is a slight saving due to composition on standing matter from the BULLETIN used in the *Proceedings*, this actually amounts to very little. I believe that some plan for reducing the printing expense without decreasing the value of the publications can be devised. I, therefore, suggest that the Publication Committee be authorized to make such change in the procedure as will insure the necessary funds for improving the BULLETIN and at the same time make provision for continuing the bound volumes either of the BULLETIN itself or of selected portions of the BULLETIN which can be printed at the same time as the regular issues and afterward bound up in permanent form.

In conclusion I wish to call attention to a fact which may not be fully appreciated by the membership of the Society.. Owing to the fact that the Secretary conducts most of the correspondence of the Society and does all of the advertising his work is most conspicuous. As a matter of fact the President and the Treasurer are constantly at work in the Society's interests. As a member of the Executive, Publication and Program Committees the President is in almost continuous correspondence with other officers and with members and non-members. All proof goes through his hands and it is carefully read. All questions of policy are submitted to him and he must approve all expenditures. Similarly the Treasurer is a member of the Executive and Program Committees and there is a continual stream of correspondence going through his office. The Vice-presidents and the Junior Past-president also come in for a liberal share of work which is always given prompt and careful attention.

Respectfully submitted,

HENRY H. NORRIS,

Secretary.

Council Letter Ballots Taken During 1912–13.

August 15, 1912. By letter ballot the Council elected the following members: B. H. Brown, L. H. Harris, Francis Mallory, I. P. Morrison, J. W. Muldowney, T. M. Roberts, L. B. Taylor, H. E. Webb (8). On the same ballot the Council minutes of the Boston meeting were approved.

January 15, 1913. By letter ballot the Council elected the following members: Samuel Applin, E. S. Barney, F. C. Biggin, C. W. Bloemker, R. W. Brink, W. W. Carlson, W. G. Catlin, M. M. Cory, J. S. Crandell, Hardy Cross, H. S. Dickerson, E. B. Durham, R. E. Edgecomb, B. G. Elliott, G. W. H. Fawkes, J. H. Felgar, G. A. Gabriel, W. P. Graham, M. B. Greenough, P. R. Hall, A. E. Hill, F. J. Holder, D. R. Jenkins, S. S. Keller, R. H. Krewson, E. M. Lawley, H. N. Lendall, O. C. Lester, F. C. Loring, W. R. McCann, C. C. May, W. F. Morgan, J. J. Morris, J. L. Mounce, J. F. Murphy, A. B. Newhall, F. A. Randall, F. J. Rankin, A. T. Robinson, R. A. Seaton, G. W. Smith, H. J. Spooner, A. C. Stevens, F. G. Tappan, F. W. Taylor, Alfred Thompson, E. B. Thurston, L. L. Thurstone, J. P. Tivey, L. L. Vaughan, Chauncey Wernecke, J. E. Woodman (52).

June 1, 1913. A letter ballot was taken to permit the following changes in the Constitution to be brought before the Minneapolis meeting.*

Art. 6, line 9. Change "Proceedings" to "Bulletin."

Art. 8, change to read: "Art. 8. *Publications.* The publications of the Society shall include a monthly Bulletin to be published from September to June inclusive. The Bulletin shall contain the proceedings of the Society and such other material as the Publication Committee shall determine." Results: 22, Aye; 7, No.

Respectfully submitted,
Henry H. Norris,
Secretary.

* N. B. At the meeting it was decided not to make the above changes.

APPENDIX.

BULLETIN ADVERTISING BY MONTHS.

Month.	Amount.
September	$ 112.75
October	137.00
November	101.00
December	157.00
January	132.00
February	118.75
March	113.75
April	111.25
May	104.25
June	108.75
Total	$1,196.50

TREASURER'S REPORT 1912–1913.

To the Society for the Promotion of Engineering Education:

The Treasurer would respectfully report the condition of the Society's finances as follows:

COMPARATIVE BALANCE SHEET, 1911–1912 AND 1912–1913.

Assets.

	1913.	1912.	Increase.	Decrease.
Cash	$1,763.26	$2,194.01		$430.75
Non-members—arrearage, Members—arrearage	1,558.46	1,092.47	$ 465.99	
Proceedings, Inventory	3,942.75	3,014.00	928.75	
	$7,264.47	$6,300.48	$1,394.74	
			430.75	
			$ 963.99	

Liabilities.

	1913.	1912.	Increase.	Decrease.
Accounts payable*				
Members paid in advance	$ 105.29	$ 63.50	$ 41.79	
Life Membership	310.12	300.00	10.12	
Due non-members	.99		.99	
Surplus	6,848.07	5,936.98	911.09	
			$963.99	

* There are outstanding accounts for which bills have not been presented. As far as the Treasurer's accounts are concerned such become payable only when audited.

TRADING ACCOUNT.

June 1912—Inventory		$3,014.00	
Cost of Proceedings, Bulletins and Reprints, 1912–13 (Schedule F)		4,356.77	
		$7370.77	
Less Inventory of Proceedings, Bulletins, Reprints on hand, June, 1913 (Schedule C)		3,942.75	
Cost of Sales			$3,428.02
Balance, Profit and Loss Account (Profit)			172.79
			$3,600.81
Advertising	$1,229.25		
Less Discount	17.84	$1,211.41	
Math. Report		699.71	
Bulletin and Proceedings		1,514.84	
Reprints and Scientific Management		174.85	
		$3,600.81	

PROFIT AND LOSS ACCOUNT.

Expenses on Boston Meeting	$ 344.60	
Expenses on Atlantic City Meeting (Schedule H)	5.85	$ 350.45
Secretary's Office Expenses (Schedule I)		1,958.78
Treasurer's Office Expenses (Schedule J)		291.82
		2,601.05
Profits for year		1,079.59
		$3,680.64
By Trading Account		$ 172.79
Dues		3,474.00
Interest on Bank Balances		33.85
		$3,680.64

BALANCE SHEET.

Assets.

Accounts Receivable: Members, Back Dues (Schedule A)	$ 253.50	
Current Dues (Schedule B)	815.60	
Members and Non-members, for Advertising and Publications (Schedule C)	489.36	$1,558.46
Cash: Lincoln Trust Company	1,453.14	
Union Square Savings Bank (Life Membership Fund)	310.12	1,763.26
Inventory: Proceedings, Bulletin, and Reprints		3,942.75
		$7,264.47

Liabilities.

Members, Dues paid in advance (Schedule B).....	$ 105.29	
Due Non-members (Schedule E)	.99	$ 106.28
Surplus, June 18, 1912	5,936.98	
Less Members' Dues of prior years, dropped this year	168.50	
	5,768.48	
Profits for year (See Profit and Loss Account)....	1,079.59	
	6,848.07	
Life Memberships	310.12	7,158.19
		$7,264.47

MEMBERSHIP.

	No. of Mem.	New.	Res. or Dropped.	Total
June 1911	1071	114	83	1102
June 1912	1102	107	51	1158
June 1913	1158			

It will be noted that the Treasurer's accounts are kept in accordance with the following schedules, which are not printed as they are quite extensive. These schedules are kept filed for reference by members of the Society in the Treasurer's office. (A) Back dues, (B) Current dues, (C) Accounts receivable for advertising and publications from members and non-members, (D) Members paid in advance, (E) Due non-members, (F) Printing (sundry, BULLETIN, *Proceedings* and reprints), drawing and engraving and editor's salary, (G) Inventory of *Proceedings*, BULLETIN and reprints, (H) Expenses of meetings, (I) General expenses such as postage of all kinds, telegrams, advertising of publications, expressage and freight, clerical assistance, insurance, committee expenses, Secretary's salary, etc., (J) Expenses of the Treasurer's office.

As announced in my last report I have deducted from each payment for dues the sum of one dollar for a subscription to the BULLETIN. This is in accordance with the requirements of the Post-office Department. The income from the sale of BULLETIN and *Proceedings* in the Trading Accounts is, therefore, increased and the income from dues appearing in the Profit and Loss Account is decreased by a number of dollars numerically equal to the net membership.

Respectfully submitted,

W. O. WILEY,

Treasurer.

PROCEEDINGS OF THE TWENTY-FIRST ANNUAL MEETING.

ADDRESS OF WELCOME ON BEHALF OF THE UNIVERSITY OF MINNESOTA.

BY FRANCIS C. SHENEHON,

Dean of the College of Engineering.

Mr. President and Members of the Society: It is my very pleasant duty on behalf of the Faculty of the College of Engineering to welcome you to Minnesota. You will realize that the College of Engineering of this university is one of the youthful technical schools of the country. Whatever of transition and unfinished conditions you see, therefore, you will credit to present progress.

I regret that our president, Dr. Geo. E. Vincent, is not here to welcome you for the University. He has put into manuscript certain words of welcome, perhaps not the exact words he would have spoken had he been here. It is my pleasure to read these written words to you.

"*To the Members of the Society for the Promotion of Engineering Education, Gentlemen:* It is a source of regret to me that I cannot in person welcome you to the University of Minnesota. Your presence here affords pleasure to our academic community. Back of the highly-specialized pursuits of our educational work lies a common interest in scientific processes, in practical applications of truth and in a more efficient social service.

The College of Engineering of this university feels particular satisfaction in your visit. We are building up in this urban center an engineering school in which we take increasig pride. You have an opportunity to observe our engineering equipment. We feel rather complaisant about this, but

we are more concerned with the thoroughness of our instruction and the value of our work to the people of the state.

The service of your association in fixing educational standards is, I am sure, appreciated by institutions everywhere. In the absence of such bureaucratic control as Germany and France provide, voluntary co-operation is the characteristically American method. What it lacks in uniformity and authority it makes up in spontaneity and resourcefulness.

I have not the technical knowledge which would enable me to make contribution to your deliberations. I have only one thought to suggest. The contrast today between vocational and cultural studies may be over-emphasized. You have a problem to include in your curriculum an increasing number of technical and professional pursuits, and at the same time to retain even a slight trace of those studies which used to go by the name of the "humanities." There is a certain wistful pathos in the thought that a little French or German, a smattering of English Literature, a course in Economics or Civil Government, are supposed to represent the "cultural" element in the engineering course.

We are beginning to revise our ideas of culture. We are trying to give the term a new meaning for the modern man. We do this by translating the old cultural attitude into new relationships to life. The engineer has in his calling two obvious sources of cultural appreciation,—the romance of his work, and its bearing upon the welfare of mankind. Kipling has shown us the opportunities of idealizing the mechanisms of today. He appeals to the imagination and stirs the hearts of men. The young engineer may well cultivate in himself this romantic feeling for his work and from this gain a deepening culture. To think of himself as a social servant, to have a vision of what his work means in the life of the world, to know that upon it depends the safety, the comfort, the happiness of millions,—this is to feel the thrill of a common life. To foster these ideals is a part of your task of which I am sure you are not neglectful.

May your deliberations mark new progress in the standards and ideals of your profession. May you strengthen the bonds of comradeship and deepen that sense of corporate co-operation which gives to each man the wisdom and the courage of his fellows.

Sincerely yours,

GEO. E. VINCENT."

RESPONSE. ON BEHALF OF THE SOCIETY.

BY WILLIAM T. MAGRUDER,

President of the Society.

Dean Shenehon and other Members of the Faculty: On behalf of the officers and members of the Society, I desire to express to you, to the College of Engineering and to President Vincent of the University, our very sincere thanks for the words of welcome and advice. Some of us have already been feeling at home since coming into your hospitable city. Some of us have been here before. For myself I feel thoroughly at home for the reason that, while I was not born here, my father, an army officer stationed at Fort Snelling, helped to make this place habitable for you and me by engaging in the Indian wars some sixty years ago. Hence tradition in my family makes Minneapolis quite a home city to me. Your words of welcome are very acceptable and will be passed on through me and the other officers to all the members of the Society.

THE GOOD ENGINEERING TEACHER, HIS PERSONALITY AND TRAINING.

PRESIDENTIAL ADDRESS.

BY WILLIAM T. MAGRUDER,

Professor of Mechanical Engineering, The Ohio State University.

At the meeting of Section E on Engineering Education of the World's Engineering Congress which was held in Chicago in 1893 in connection with the World's Columbian Exposition, there were assembled "seventy or more" engineering educators from the United States and eight or more foreign countries. This society owes its existence to the Congress and to the thought and labors of Professor Ira O. Baker, chairman of the Division Committee, and Professor C. Frank Allen, its secretary, pro tem. Of the seventy charter members, twenty-nine have either gone to their reward or have withdrawn from the Society. Only forty-one of the seventy are now members of the society. Eleven of the living past presidents are charter members, three became members in 1894, and one each in 1895, 1897, and 1902. That was twenty years ago. Some of us are no longer boys, even if we do feel as young and as full of enthusiasm as we did then. If time and your patience permitted it, and I were able, it would delight me to recall in great detail the lives and examples of some of the giants in engineering education whose successors we are—of the cultured Thurston, of that dynamic giant, DeVolson Wood, of that inventive genius, Robinson, of the courtly Chanute, of the erudite Johnson, and of the versatile Storm Bull. I offer you my congratulations on being allowed to follow where they have led the way.

But after twenty years of this society's existence for the promotion of engineering education, at this its twenty-first meeting, when our growth betokens that we have come to our legal majority, at least in years, I desire to lead your minds

into the consideration of what is a good engineering teacher and to give you an appreciation of his personality, and what he is as I have seen him in three score and more of engineering colleges and technical schools.

What then is a good teacher? And my first answer is that he is one who knows enough of his subject to have something to impart. I sometimes think the reason men from the highest ranks of consulting engineers so frequently make poor teachers, from the point of view of the students, is that they know too much, and cannot appreciate the fact that the students are down in the basement of the structure whose facade they are embellishing with artistic points of elegance and efficiency, and that the students are crawling on hands and knees along the path they are traveling with seven-league boots. In order that the teacher shall have something to impart, he should have had a proper education and some training, experience, travel, and observation, as these are among the necessary qualifications for a good teacher. The man who has never earned his daily bread in the close commercial competition of the factory, works or mine, needs to learn one of the essential requirements of the successful engineering teacher, namely to have rubbed elbows with workingmen of the artisan type and to have measured himself by their standards of knowledge and skill. One who has received only the education that he is trying to impart, possibly at his alma mater, probably in the same room in which he received it, who has never cut himself loose from his college's apron strings, and who has not taught or worked elsewhere, is not likely to make a good teacher until he has been trained in the school of experience elsewhere. If graduate students should migrate for their best good, surely college teachers should do the same. In a previous paper before this society, I have already referred to one institution, almost one hundred per cent. of whose teachers in one department are the educational offspring of the great mind which presided over the department for thirty years. Experience of any kind always serves a teacher well, and the more he has had of that which

pertains to the subjects that he is teaching, the better it will be for him and his students. Travel and inspection trips, to learn by observation how others are doing the same thing that he is expected to do, are extremely broadening and take him out of his natural groove. It is needless to say that continued reading and increase in one's knowledge of his profession is absolutely essential for the advancement of the good teacher.

A good teacher is one who can talk on his feet audibly enough to be heard without effort and intelligently enough to be understood without subsequent correction. For, if the listener cannot hear what is being said for his instruction, both parties are wasting time which is more or less valuable. If the recipient of the instruction continuously fails to get an intelligent understanding of what has been said, he has no right to be in attendance; and, similarly, if the teacher continuously fails to give an intelligent understanding of what he is trying to say, he should be removed and not allowed to waste the valuable time of the students. A man who cannot impart his knowledge cannot be a good teacher. Hence, health, adequate previous rest, and endurance are essential to the good teacher. Few of us, I think, appreciate the difference in the instruction given and taken in September and in May, on Monday and on Friday, after a holiday spent in restful occupation and amusements and after an entertainment lasting until far past midnight. Some of us occasionally fail to consider and measure accurately the cash value of an hour of a class's time. We should be greatly disturbed if in our factory the power were needlessly shut off during the working hours of the day, or the lights went out at night, or the subsistence department failed to provide suitable food and lodging for our workmen, and we would at once discover the causes for this industrial inefficiency; but if the class is made to wait while a visitor or an assistant detains us, we may have little remorse, or indeed thought, concerning our academic inefficiency. To attend an engineering college it costs a student at least one dollar per week per credit hour of col-

lege work, or from sixteen to twenty dollars per week. If therefore the teacher in a college of engineering is absent without a substitute from a one-hour class-room engagement, it may be causing each of the ten to two hundred students to spend a dollar in needlessly trying to fulfill his part of the contract with the institution. The same is true of inexcusable latenesses.

A good teacher is one who has an unimpeached and deserved reputation for mental honesty, right living, patience under harassment, and sound character. The engineering teacher who describes tricks of the trade, petty dishonesties, evasions of both the spirit and the letter of the law, without showing at least his disapproval of them, who shuts his eyes to dishonesties in class-room and college life is neither a good teacher nor yet a good citizen. The teacher who is a leader in trickery, deceit, and bluff during the term and who permits students to sit in an examination room so close together as to be under constant temptation to undesired dishonesty is particeps criminis to any dereliction of the student then, and possibly later. When cheating in examinations is made a sine qua non for honors and high grades, if not for graduation, and when the most skillful compiler of invisible ponies and the most successful cheater becomes the honor man of the class, as I have heard reported in recent trips among the colleges, it would seem that an old fashioned course in moral philosophy and ethics should be in order for both the teachers and the students. We all fail, I fear, frequently enough, but we should not be forced, or allowed, to fail inordinately. Occasionally we hear condonation expressed at the human frailties of the teacher, because he is considered as a genius in his specialty, and on account of his lovable qualities. Far be it from me to cast stones at my brother man, but I have never been able to discover a reason why a drunkard, or a libertine, should be tolerated in the teaching profession and frowned out of society in other professions and not allowed to work where the physical well-being of others was involved. Surely the mental and the spiritual well-being of our young

men are paramount to their physical existence. The one moral trait which seems to be most frequently demanded above all others from the teacher is that of patience. Some of us do not enjoy walking with persons who walk slowly or with very short steps, and who take a long time to get over very little ground. Similarly, we have to go equally slowly in expounding a new problem to a class, or in drawing out of even the average student the principle underlying the problem in hand, and in causing him to think about the subject consecutively and logically. We have all asked ourselves at the end of the hour, "How many in that class really took in the full significance of what I was talking about?" If this is true with the average class, how much more is it so with those members who are lazy or are naturally slow in their mental operations?

From the above it follows as a matter of course that the good teacher should deserve the respect of his students and his colleagues as a man, as a teacher, and as an engineer. I think it frequently happens that the students know our failings and our strong points better than we do ourselves, or than they are known by our superiors. Student criticism may sometimes be unjust for want of full and complete information, but it must be remembered that the young human mind is likely to be as keen in its perceptions as is the older mind of the man who occupies the other end of the room.

Another requisite in the good teacher is unbounded enthusiasm for and intense loyalty to the work of the teacher and of the engineer. We can tolerate the hireling in the commercial office and the drafting room, and the time-server may have to be put up with out on the works and in the mine, but the teacher, as a leader of young men and as a man who should be looked up to with some degree of that kind of respect which may grow into veneration, should be so bubbling over with enthusiasm that it will be contagious.

That prince of cultured scientists, Dr. S. Weir Mitchell, in giving at the semi-centennial celebration of the foundation of the National Academy of Sciences some of his recollections

of the eminent men of science whom he had known, told the story of Professor Joseph Leidy's being asked if he never got tired of life. "Tired!" he said, "Not so long as there is an undescribed intestinal worm, or the riddle of a fossil bone or a rhizopod new to me." So, the enthusiastic teacher is never tired, so long as there is an intelligent boy to be trained or a mind to be developed. The engineer sets in motion the wheels of thousands of machines; the successful educator sets in motion the wheels of a thousand minds. Such a man can always get the work out of his students, even if they have to curtail the time properly due to some other instructor who is less inspiring. The enthusiastic teacher never counts the cost to himself of his labor for those whom he loves to call "His Boys".

I am of the opinion that our engineering colleges are less handicapped than are the academic colleges by the services of men who are teaching for a year or two either while studying for the bar or for holy orders, or to enable them to repay the debts contracted for their college education by the means which will permit the least effort during the shortest time. As a rule, the call to work in the bustle of the manufacturing and constructive world is preëminent in the mind of the engineering graduate. He is ready for the fray, and today he wants to get into it as never before, and no waiting until cooler weather or until after a summer vacation for him. "I am going to work next Monday," is his battle cry on commencement day. The courage of youth is beautiful to behold, and his zeal is a lesson to his teachers and to those who are following him.

Akin to enthusiasm for his work in the good teacher is his inspirational value to his students and his colleagues in the faculty. The former is the child of youth; the latter is the product of age and genius. When the teacher begins to lose his enthusiasm, he should begin to think that possibly he may be getting old, or else lazy. Not infrequently, however, the teacher who is devoid of enthusiasm may be of great inspirational value. He is the seer. He may be even halting

in his speech, but by his ideas, his skill, or his manner of presenting the subject he may impress the student with the greatness of the profession that he is studying and lead him on to larger visions. Fortunately, the world needs both draft horses and speed horses, otherwise some of them would have to be put out of the way. Similarly, it is a great comfort to some of us to think that possibly we are doing the work of the world for which we were created, even if we are not breathing out great ideas at every breath. All hail to the man, however, who has ideas and can cause others to adopt them, to lift the world up and into larger visions, and so to do bigger things for the benefit of mankind. Great men are not necessarily either enthusiastic or yet inspirational, and some of the poorest teachers under whom I have sat were great men in other lines of human endeavor. But I am sure we can all recall some one of our own teachers who was both a great man and a good teacher at the same time. But, may I not ask, was he not a good teacher because he was enthusiastic and insipirational, and had no thought of apologizing for being a teacher? The man who can never be a good teacher is he who is ashamed of his job, for to him it is most likely to be only the line of least effort to the pay-check.

The good teacher is he who has felt the thrill of having been called to the upbuilding of character in others, who day by day sees the unfolding of the innermost life of his fellow citizen, who has a life of service to live and enjoy, and who deals with human minds in the laboratory of life; for, after all, is not education only scientific research applied to character? Just as we go to the physician for the improvement of the body, and to the priest for the betterment of the human soul so we should go to the good teacher for the training in character which the young all need in different degrees. One of the inspiring sights of the college year and the one which always gives me a genuine thrill of happiness is on commencement day to look over the sea of upturned faces of men and women who have just been graduated and feel that we have been in some small degree a party to their training and

responsible for their future success in the battle of life and in the part that they will hereafter play, for weal or for woe, as our fellow citizens in this republic. In their promise of success is our joy and reward for a year of hard work. But for the joy of service, some of us would not be willing parties to what the Governor of Ohio recently described as "the scandal of low salaries paid to college professors". I sometimes think that school boards and trustees occasionally take advantage of the idealism of the teacher to get his services below the proper market rate; and this is especially true of engineering teachers who in most cases can, and sometimes do, earn more money from their clients during a part of the year than they receive from their professorship during the major portion of the year. All the pay of the good teacher does not come inside the pay envelope. Much of it comes in that inward consciousness of work well done in the training for citizenship, for that efficiency which will prevent poverty, for success in whatever walk of life may be followed, and finally for the larger life here and hereafter. Someone has defined the professional class as the one that has no leisure, as instanced by the minister, the physician, and the lawyer. Judged by that standard, we, as teachers, belong to the professional class.

Probably some of you have been wondering why I have not as yet said anything about the good engineering teacher being above all other things a good engineer. That goes almost without saying in this presence, provided you mean the *best* teacher. The engineering teacher who has never practiced anything that he has taught, who has never seen built anything that he has designed, who has never prepared for an elaborate test of some plant or machine and found that he had foreseen all the various requirements in the way of labor, apparatus and equipment, even to the board and lodging of himself and his assistants, cannot expect to be considered as yet a really good engineering teacher. However, it must be remembered that as this is an educational society, and not an engineering or a technical society, as Dean Charles H. Benjamin has so aptly put it, so it must be remembered that

the colleges need men who to be teachers must be first able to impart their knowledge, draw out from their students all that is in them, and cultivate in them the habits of correct thinking, clear vision, active imagination, sound reasoning powers, and good judgment; and because they possess these things themselves and can train others in them, they are therefore fit to be counted among the good teachers. It is for these reasons that good engineering teachers are said to be more difficult to find than are good teachers of other subjects.

A good engineering teacher must know what engineering really is. He must have clearly defined ideas on what are the distinguishing features of engineering, technical, manual training, trade school, and industrial educations. He must have no half-hearted ideas as to where the engineering trades stop and where the profession begins. He must not be afraid to get out into the deep water of the profession of engineering. He must not believe that the proper engineering education is strictly utilitarian and vocational, and not one bit cultural. He must look between the folds of the ancient armor of his colleague in the college of arts of his institution, and discover that the scientific spirit has largely superseded the literary spirit even in such subjects as Latin, Greek, and the modern languages; that in fact in the work of some language teachers there is more of science than of language; that the so-called literary colleges are training men for vocations just as truly as are our colleges of engineering, law, and medicine; that while the old-time classical colleges used to train men to be gentlemen, their successors in the educational world train men for journalism, insurance, politics, trade, and business, as well as for education, the law, and the ministry as heretofore. We engineers think that they are to be congratulated. in that they have enlarged their system of education and no longer make it so general as to fit the student for nothing in particular and so non-technical as to be useless except as a preparation for one of the professions.

"To know the best that has been thought and said in the

world" is what Matthew Arnold calls culture. To the engineer, this is not the fullness of culture, but the rather to know the best that other men have thought, and said and done. Even this is only half of the full duty of a cultured engineer. He should not only know the best that others have thought, and said and done, but he should, as far as he may be mentally able, have contributed to the thought, and writings, and doings of the world. The engineering, above all other professions, demands that its members shall not be solely scholars, nor yet students of unsolved problems, but they shall have solved some of the problems which have pressed upon civilization for solution. Engineering teachers should be not scholars solely, nor yet students only, but pioneers and creators in the work of civilization. The first live in the spiritual palace called a library, where time, memory, and the receptive faculties are alone required. The student lives in the laboratory where the powers of observation are developed, logic reigns, and laws are discovered. The successful engineer lives on the frontier of civilization, on the firing line of human endeavor, where those material problems have to be solved that have been set for the ages, and where the art of creation is wedded to the science of industry. The scholar deals with the past. The student lives in the present. The engineer looks into the future and solves its problems.

To be a good engineering teacher, one must be something of a scholar, student, and creator, and, highest of all, an educator capable of leading others to be the same. Such men are necessarily scarce, and while their financial rewards may be small, the satisfaction that they very properly get from their work transcends all their many self-denials and enables them to hold their heads up with the world's best people.

This society was formed for the promotion of the kind of education which has been described. This is its twenty-first annual meeting. It may be now said to be of age. In closing this address I desire to leave with the next program com-

mittee and the incoming officers just two suggestions with the hope that they may be possible of adoption.

Let the program next year include a rousing session on "Education as a Science, rather than as an Art". Those of you who are familiar with the proceedings of the society know that we have had the subject of education considered as an art dealt with from many points of view. Until this meeting, little, if anything, has been done to consider the rationale and science of our chosen profession of education. Let the best minds in the educational world tell us, and in a practical way, all that time will permit concerning the science of education, including its psychology as applied to engineering education. Schools of salesmanship have their special courses in the psychology of their chosen vocation; but did any one ever hear of a course in psychology being demanded as a part of the necessary training required for the engineering teacher? As training and instruction in the normal school are required of grammar school teachers, and as graduation from a college of arts or of education is expected or demanded from the would-be high school teacher, and since successful courses are given in our colleges of education on how to teach mathematics, chemistry, and physics, surely courses are needed on how to teach the applications of these subjects. Hence I claim that some professional training in education should be required of the man who desires to impart his knowledge and to train young men for the practice of the engineering profession. We are engineering educators. Why should we be required to possess much professional knowledge and training in engineering and none in education?

And this leads me to my last suggestion which is that the faculties of some of those universities which maintain both colleges of engineering and of education should offer in their summer terms strong courses of study in psychology and in education considered both as a science and as an art. These should be conducted by their most virile and experienced men, and college presidents, deans and heads of departments should

be requested to influence their younger assistants and fresh graduates who expect to go permanently into the work of education to take these proposed courses of study in the summer term in preparation for their work in the college of engineering in the succeeding year. If this is done, more engineering teachers will become engineering educators.

ACADEMIC EFFICIENCY.

BY H. S. PERSON,

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The purpose of this paper is to present for discussion the problem whether the principles of scientific management, as applied in industrial operations, can be applied in the business of educating young men. It is not concerned with the field of engineering education, for with that I am not familiar; nor with the field of higher education for administrative service, in which I am engaged; but with college education in its broadest aspects, education in the arts, humanities and sciences. It is not concerned, furthermore, with the purely business phases of college education—the construction and management of the plant, repairs, upkeep, purchasing, etc., for these activities are in my judgment unquestionably subject to the application of the principles of scientific management. It is concerned with the business of academic instruction, its personnel, equipment and methods; with formal instruction of the class-room and with that informal instruction which operates outside the class-room, the instruction imparted by an educational institution by its atmosphere and the opportunities for educative experience presented by the society it creates and directs.

Objections to Scientific Management in Education.

Mr. Cooke's *Bulletin No. 5* of the Carnegie Foundation, on Academic Efficiency, has brought out within the few years since its publication numerous denials of the applicability of the principles of scientific management to educational work, especially to the work of instruction. I have had occasion to examine a large number of these criticisms of the report and

find that most of them are simply statements of opinions unsupported by data of experience or investigation, unsupported even by argument. The few that do present argument present *a priori* argument only and all essentially the same *a priori* argument. It runs somewhat as follows. "The product of an industrial plant is a material thing, capable of precise measurement qualitatively as well as quantitatively; the product of an educational plant is the scholarship, culture and manliness of its graduates, attributes quantitatively and qualitatively immeasurable. The processes of an industrial plant are mechanical and subject to exact and known laws and subject to precise variation in application with reference to their effect; the processes of education are functions of the contact of minds and personalities. The material of the industrial plant is matter, capable of as precise quantitative and qualitative measurement as is its product; the material of the educational plant is the human mind and human nature, intangible and immeasurable, and never the same in two individuals. The principles of the organization and administration of the one cannot be therefore the same as those of the other."*

Insufficiency of these Objections.

It seems to me that argument of this kind does not settle the question but merely opens it. It embraces a number of assumptions which sound true, and in a large way are true, but which should be subjected to investigation and experiment. Since my interest was aroused by analysing these opinions I have observed numerous facts which raise doubts of their validity.

In the first place, they assume that instruction is imparted by personal contact of instructor with student in the way it is done in the ideal college, a log with Mark Hopkins at one end and a student at the other. Now I am free to state that I know of no more efficient educational organization than this, as to personnel, equipment or method. I wish I could afford

* "Academic and Industrial Efficiency," by H. S. Person, in *The Dartmouth Alumni Magazine*, Vol. 4, No. 4, Feb., 1912.

for each of my children a Mark Hopkins and a log; I should then not be concerned with material, method or organization, and I should not fear for results. But I cannot afford it; neither can a democratic society educating its youth on a large scale afford it. Furthermore, the supply of Mark Hopkins is limited. We are educating and must educate our youths in groups, and the moment education by groups becomes a fact, that moment personal contact between instructor and student diminishes, in some instances, as in lecture courses, to almost nothing, and organization becomes a necessity and a problem. Efficiency in organization must make up for diminished personal contact; or, to put it more accurately, efficiency in organization must *restore* personal contact.

Functionalized Educational Operations.

With education in groups must come, if we would restore the Mark Hopkins efficiency, functionalized educational operations. Mark Hopkins with his one student on the log could instruct formally, supervise the study of his student, talk with and influence him "out of the class-room," be his social influence. The non-formal instruction of a Mark Hopkins under these circumstances is perhaps the greatest education. But in our colleges and the undergraduate departments of our great universities, with one, two, three, four and even five thousand students, with the diminution of personal formal instruction has resulted practically the disappearance of informal instruction, the contact outside class room between instructor and student with its advice, encouragement and inspiration. To meet this situation organization must arise and restore something of the equivalent of what has been lost. The many functions of the one man educating one student must be replaced by the same functions, distributed one each among many educators instructing large groups of students.

Social Problems of Large Colleges.

Furthermore, large educational institutions with large aggregations of students, most of them away from home for

the first time, have social problems which the one-man-one-student institution cannot have. Students in masses, like other people in masses, are subject to a mob psychology which causes the break-down of conventional rules of conduct and conventional ideals. Unquestionably one of the valuable educative factors of an educational institution is the broadening of the mind manifested in a moderate reconstruction of habits of conduct and ideals developed in the narrow environment of home life; but it seems to me that in many instances this reconstruction, when undirected, takes place too rapidly, goes too far, and particularly goes too often in the wrong direction, so that the student when he leaves college has to experience still another adjustment to the society he enters. An educational institution is a trustee representing the parents of every one of its students, and as student aggregations increase in size should by organized mechanism attempt to direct the formative mental and moral influences working outside the classroom but within its proper jurisdiction.

Applicability of Scientific Management to Education.

It appears, therefore, that the *a priori* arguments against the applicability of the principles of scientific management in instruction, both formal and informal, are grounded upon false premises; that they premise a Mark Hopkins, a log and one student, whereas our educational institutions are great aggregations instructed in groups; and that in so far as personal contact between instructor and student tends to diminish, organization must become more complex if efficiency be preserved. As organization becomes more complex the principles of scientific management become more applicable.

I propose now to consider in detail some of the principles of scientific management and some of the educational problems to the solution of which they might be applied, which have come under my observation. I shall consider only a few of the main principles of scientific management as conventionally classified.

Educational Science a Necessity.

A principle of scientific management is that its methods are the methods of a true science; that in attempting to solve problems of industrial organization and management it employs the method of elaborate investigation, experiment, correlation of data and analysis. One would expect that an educational institution, in the laboratories of which is kept burning and handed on from generation to generation the sacred fire of scientific method in research, would employ these methods in attacking educational problems. But as a carpenter is said to have the most defective sidewalk, and a lawyer to have inefficient counsel if he is his own client, so are educators least scientific in attacking problems of education. Inefficient investigation, incomplete presentation of facts, irrelevant arguments and snap judgments are most common. This situation is not to be attributed to incompetence. The absence of functionalized responsibility is the principal cause. Instructors are overburdened with duties of formal instruction and preparation for it, and cannot enter with enthusiasm into the performance of the function of solving educational problems. They look upon the latter function as one to be got out of the way as quickly as possible and with as little interference as possible with study and formal instruction. The point I wish to make here, however, is that, whatever the reason, educational problems are not attacked and solved by scientific methods. I recall the story of a committee report on an important matter which had been referred to the committee by the faculty of a college. The committee reported "inexpedient to legislate," and without giving reasons for its conclusion explained that it had investigated the problem as existing in the principal other institutions and had spent all of six hours on it! No wonder the committee could not present reasons after a six-hour investigation! Incomplete and unscientific investigation and an inefficient report on the matter referred to the committee deferred five or six years the adoption of legislation which later marked a step forward in the educational efficiency of that institution.

The Need for Statistical Study in Education.

In educational institutions, as in some industrial plants, there is a horror of so-called unproductive labor. Industrial concerns are learning that this kind of labor is oftentimes the most productive, and are increasing their cost-accounting, statistical and informational forces. Educational institutions might well follow in this respect the most advanced industrial practice. The principal records kept by educational institutions relate to marks and attendance, a simple ledger account with students. Every educational institution should have a force of statisticians accumulating and correlating data which might guide the institution in determining what policy to pursue. Labor of this sort, engaged in applying scientific methods to the investigation of educational data, would be most productive by increasing the productivity of those who actually meet and instruct students.

The following are some of the problems which might be scientifically investigated by such a statistical bureau. What is the best working size of a class-room division for each subject taught? What is the proper length of a recitation period for each subject taught; should some occupy one, some two and some three units of time? Which would be more efficient, three recitations per week in one course, or six, or five? Is there a season of the year in which best work is done by students, and should assignments be adjusted accordingly? Is it possible to establish standard assignments (say in modern language instruction) varying according to the text read and the part of the text being read at a given time? Is it better for all students concerned to meet and instruct them in chance-assembled groups, heterogeneous as to scholarship, or in groups determined by scholarship? Is it possible to determine standard pedagogic methods for teaching different subjects and to acquaint instructors with them? These are a few of the many detail problems of efficiency which confront educators. They have not now data on which to base judgments, and they have not the time to accumulate and correlate such

data. Only an organized statistical bureau in each institution can properly perform this function.

Functional College Organization.

What I have said about functional investigation of educational problems suggests the general application of the principle of functional organization, another principle of scientific management. There should be functional teaching (the activity most nearly specialized at present), functional administration (discipline), functional advising and functional supervision and guidance of non-classroom educative influences. Today the obligations of the instructor embrace practically all institutional functions except general administration. I have read in *Popular Science Monthly* during the past two years numerous articles asking that the teaching force of each institution be made to assume that function also! The result of placing on the shoulders of the instructing force the burden of the performance of so many functions is that none is performed efficiently, not even instruction itself as efficiently as it might be. I have shown that the function of solving educational problems is performed inefficiently. In administration there is a tendency to handle students at arm's length, so to speak, by general inflexible rules of administration, and not to consider each case of discipline by itself, to be decided according to the particular circumstances and rules of equity. Contrary to the opinion of many, I believe that the larger the number of functions imposed upon an instructor, and consequently the greater his burden, the more impersonal becomes his relationship with students. He is compelled by the very burden of duties to perform them through regulations which operate impersonally. Some educators argue that teachers should never give up their administrative duties because it is they alone which keep the instructors in touch with students. It is, on the other hand, these very duties which shut the instructors off from personal contact with students; which makes the contact they seem to have unreal and gives them a false view of students. An instructor

who does nothing but teach, but has leisure for informal intercourse with students, can learn to know the student as he really is, and by the power that knowledge gives him can "reach" the student and inspire him in the class-room.

The Advisory Function.

One of the great functions of the teacher in the Mark Hopkins-one-log-one-student type of college is the advisory function. If I were to send a son of mine to such a college, I should expect the largest educational results to come from the advice "out of school" about all sorts of things—informal talks about literature, science, sports, ideals, conduct, how to study, how to play, what things are worth while, what things are not worth while. The large modern educational institution has lost the power to perform this educational function, but it has not lost the responsibility, and it will some day be held to account. Theoretically the instructor performs this function, either informally on his own initiative or formally through an advisor system, but the performance can be perfunctory only. In the first place, it is one of the several functions too many the performance of which is left to the instructor. In the second place, few men are temperamentally capable of being disciplinarian and sympathetic advisor also. In the third place, in the cases of those few instructors who are temperamentally capable of being both disciplinarian and advisor, there are in the student mind obstacles to advisory relationship, for the student, if he knows his advisor to be disciplinarian, assumes that he cannot be sympathetic advisor, and this state of mind at once defeats the establishment of advisory relationship. In the fourth place, many instructors are not broad-minded enough to be advisors, and the function should not be entrusted to them.

I consider the advisory function one of the most important responsibilities of an educational institution, and it should be entrusted to functionalized advisors, picked men. I have seen many college students' careers made relatively inefficient because of lack of counsel at critical times. I have also seen

careers made relatively inefficient because of unwise counsel given. How many college graduates do you suppose there are, who wish that they could have had many talks during their college years with some large-minded, sympathetic man, who could have told them what things are worth while!

It is a principle of scientific management that the determination of *how* be entrusted to specialists and not left to the workman, thereby eliminating the waste of misapplied effort. The advisor in an educational institution would save much wasted energy of students by relieving them of the necessity of deciding the *how* in situations which they have not the experience to decide safely.

Results of Functional Organization.

Functional organization would deprive the individual instructor of many of the duties he now performs, but it would leave him free to make himself more efficient in his primary function—instruction. It would enable the institution to perform, and the student to receive the benefit of, a wider range of efficiently performed functions than is possible at present.

Other principles of scientific management have been suggested by what I have already said. To apply one principle makes necessary application of all the others, for the body of principles of scientific management is an organic whole; each principle is but an angle of view of all the others. Functional organization involves wise selection of men (instructors, advisors, disciplinarians, etc.), wise selection of equipment (pedagogical methods and apparatus), and wise classification of material (students; according to scholarship, natural ability, preparation, health, temperament, etc.). It requires these wise selections and, what is more significant, it, and it alone, makes these selections possible.

Scientific Management and Rewards.

Scientific management has discovered that men can be inspired to more efficient self-instruction, more efficient following of instructions, and to higher levels of energizing, by

reward according to productivity, in some tangible form and immediately. An immediate, tangible, practical reward for efficiency is unquestionably a powerful force. Is it not possible that something more could be made of this principle by educators? The reward of being permitted to play on a football team, provided he is not below a certain rank in scholarship, has inspired many an athlete to better scholarship than he would otherwise have shown. The reward is practical and immediate. On the other hand, I have had seniors tell me that they would have tried for Φ B K, had the reward for hard work not seemed so far away to them as Freshmen.

Scientific Management and Academic Freedom.

One response to suggestions that efficiency in instruction could be increased by wise application of the principles of scientific management is the criticism that it would diminish academic freedom, suppress the individuality of instructors and deaden the spontaneity of the class room. I insist that, on the contrary, it would increase academic freedom, bring out the individuality of the instructor, and enable him to bring before his students more of the power to arouse and inspire. The teacher who is relieved of the burden of too many functions would find himself freer to investigate widely, think deeply, know life and form individual judgments. It would enable him to find the way of and time for self-expression. The erect figure, the keen eye, the intense earnestness, the precise statement of fact and principle, the wise choice of interesting and illuminating illustrations, characteristics which, in addition to scholarship, make the great teacher, would continue to exist and to arouse and inspire.

Discussion.

Professor A. E. Haynes: After an experience of five years as an undergraduate and nearly forty years of teaching, about thirty-seven of it in college, and after a cessation of the steady strain of the class-room for a year and a half I think that I am prepared in some degree to act the part of a just critic since,

through all these years, both as student and teacher, I have been deeply interested in education, including both the subject matter and the methods of instruction.

At the close of my undergraduate work, in a public address at Commencement, I stated, as a result of my previous five years of experience and observation, that I was satisfied that too many studies were required of the student to make him efficient in any. Since that time new studies have been steadily added to our curricula until they have become so overcrowded that they defeat the fundamental purpose of education. Too many studies in too little time produce confusion and lack of confidence on the part of the student. Too many lines of thought tend to distraction; they lead one nowhere; they do not develop the mind. The power of abstraction is the most important, the finest fruit of right education; it is not born of confusion; it is the child of painstaking, thorough, clear-headed, logical mental development. Intensiveness is not the child of extensiveness.

The curricula of our schools, from the kindergarten to the university, are crowded beyond all reason and all hope of producing the best results. To be able, parrot-like, to recite rules and formulæ is not education any more than walking thru a botanical garden makes one a botanist. It is that which the student masters that makes him a student; going through books does not necessarily educate him. There is a great difference between one's going through a book and having the book go through him.

Scholarship is not measured so much by its breadth as by its depth. The disciplinary and the cultural value of a course does not depend so much upon the number and kind of subjects in the course as upon the way in which it is taught and studied.

Why is there a great cry for efficiency at the present time? It is because education has been made a stuffing process, instead of a process of evolution. The teacher is not so much to blame for this state of affairs as is the poor system under which he is working. The time properly spent on one-half of the

number of studies which are now required would lead to a higher efficiency, to a thoroughness and to an independence in thinking not now possible. Our whole system of education needs some heroic surgery, and it should be subjected to a major operation. Have we the courage to begin this work? If so I hope we shall not be slow in doing our best.

In conclusion, may I quote from that excellent work by Hon. John M. Gregory, "The Seven Laws of Teaching"? These are worth writing in every class-room, in letters of gold.

1. "A teacher must be one who knows the lesson on truth to be taught."

2. "A learner is one who attends, with interest, to the lesson given."

3. "The language used as a medium between teacher and learner must be common to both."

4. "The lesson to be learned must be explicable in terms of truth already known by the learner—the unknown must be explained by the known."

5. "Teaching is arousing and using the pupil's mind to form in it a desired conception or thought."

6. "Learning is thinking into one's own understanding a new idea or truth."

7. "The test and proof of teaching done—the finishing and fastening process—must be a reviewing, a re-thinking, a re-knowing, and a re-producing of the knowledge taught."

This book and "Watt's on the Mind" were a great inspiration and help to me in my active teaching and each is worthy of a careful reading and re-reading.*

Principal A. L. Williston: Regarding the proper number of subjects to be taught we can very easily make some kind of an investigation to find what are the best methods of developing young men. At one time it was my duty to have to assign a special program to every student who got into difficulty with the regular course at The Ohio State University. As an ex-

* The first of these books is published by the Congregational House, Beacon Street, Boston, Mass.; the second by A. S. Barnes & Co., Chicago, Ill.

periment I tried to determine how many subjects that type of student could carry to advantage. And four years of study I found they could carry to advantage not less than three subjects and not more than five. A comparison of the number of subjects taught in the different years of the course in the various colleges of engineering shows results in harmony with that conclusion.

The four broad principles of scientific management as applied to engineering are very simple. The first is, by some method of unprejudiced observation, to determine what is the best way of producing the thing you want to produce. Surely that principle is applicable to education. The second is to find by test, by competition if you please, what men are best capable of doing the things as they ought to be done. Surely we can find out in some way who are the individuals who can teach by the process that we have determined to be the best. The third is to devise a method of teaching them how to do it in the proper way. That can be done but is not done in the teaching profession. We could have people who would help our younger teachers learn how to teach well, if we knew what the best methods were. The fourth is to make it really worth while for the people who are to do the work to do their very best. To a limited extent only are we doing this.

Professor H. Wade Hibbard: The history of the introduction of scientific management in the industries entirely parallels the need of the introduction of scientific management in teaching. The necessity for the introduction of scientific management in industries exists because of the increase in the size of the industries. There has, therefore, been a need of a reversion to type, namely a reversion to the small industry where only a dozen or a score of men were working intimately together to turn out the best product. We have heard it stated here this morning that the ideal university is Mark Hopkins, one log and one student. I believe that, as in the industries, scientific management has enabled the big plant to remain big but to revert to the type of the little plant, so scientific management principles in teaching will enable us

to revert to the Mark Hopkins-one-log-one-student type of university.

Dean F. L. Bishop: I have had some interesting experience in regard to the number of subjects required in the engineering curriculum and remember very distinctly the pleasure (?) I had in taking fourteen final examinations at the end of one term at the Massachusetts Institute of Technology in Boston. In looking through the engineering catalogs at the present time one is struck with the fact that there are now practically only four or five subjects taught. At that time there were really only four or five but they were all split up into little branches, with a different instructor assigned to each. Each instructor held his special examination and each had his own methods of teaching. Today we are bringing these little subjects together under general heads.

I must disagree with Professor Person regarding the log with Mark Hopkins on one end and a student on the other. A student educated in that way today would be absolutely useless to the community unless the modern Mark Hopkins happened either to be a practical politician or a practical engineer. As for educating an engineering student in that way, to do so would be to render him worthless to the community for many years after graduation. But that system has gone. We are not so much interested in developing engineers as we are in developing individuals so that they may be of the greatest service to the community. If a student is not taught in his years in college that he is to be a part of a great community in which he is to live and that he must contribute to the welfare of that community he certainly cannot serve as a good citizen after he graduates.

Dean C. M. Woodward: From my teaching experience I have had demonstrated how efficient a man can be with a reasonably small section of students. The increase in the size of our institutions ought not to have diminished their efficiency because the number of thoroughly efficient teachers should increase as rapidly as the number of students. Unfortunately it does not. As dean I sometimes advised gradu-

ates of the engineering school to go to schools more completely equipped than ours for graduate work where there were superior teachers and ony a few students. The teacher who knows what every single student before him is doing, knows just where he stands in a subject, knows the difficulties which he is meeting and, almost before he opens his mouth, what questions he is going to ask, he is the man who can do efficient work with his students and no other can.

A teacher wrote me not long ago stating that he had a class of one hundred and fifty in descriptive geometry. Just think of a hundred and fifty students listening to a lecture on descriptive geometry! The teacher never asked a question of the students and he never met an individual student. He was obliged himself to solve every problem brought before him. I wrote him thus: "Good Heavens, how can you chew up all that food for them to swallow?" This teacher had a half-dozen young men to look over the drawings that were made by his students, and they may have told the boys whether these were right or wrong, but the man who lectured to them didn't know about it. Now that is not the way they do business where business is done well. For example, I went into the counting-room once with Mr. Armour to see where his business was really done. We went into a large room where the employees were set off in sections, each under a leader. He pointed out several $10,000 men and stated that each one was responsible for his own department. In every department was an efficient man, one for every big task. In no other way can administration be efficient. That is the way in which universities should be run, whether they have five thousand students or only fifty. They should be officered proportionately.

President A. Ross Hill: I am interested in the problem which is under discussion as I suppose nearly everyone in university administration is, and more particularly because I have always kept in mind the problems of teaching. The great problem in teaching is to develop in the student the power to think and to do, and the inspiration to think and to do. Now that power can only come by solving problems, and

not by the assimilation of facts as a result of solutions made by other people. It is perfectly clear to me that an efficient organization for educational purposes must reduce numbers to a reasonable point for personal teaching. I cannot go so far as the author of the paper, if I understand it correctly, in saying that educational organization will lessen personal instruction. Education, or teaching I should say perhaps, is a social function, and man is a social being. No man who has personality to do something more than to stick to a class-room is at his best at one end of a log. He must come face to face with a reasonably-sized body of students in order that the inspirational force of his life and of his thinking may be felt by them. But we do not need to reduce the situation to an unsocial unit. We can keep our classes at a reasonable size and get the greatest efficiency.

Our faculty at the University of Missouri demands a teacher for every twenty or twenty-five students, particularly in the largest classes. The classes, of course, should run smaller than that, but when one has to go to the legislature for appropriations he finds it rather difficult to get the members to think that an allowance of ten students to a teacher does not involve a tremendous waste of money to the state. So much for the organization and the size of classes. I think we must keep both the class-room and laboratories at the point where the teacher gives the problem and the student tries to solve it, but where after all the teacher makes the student solve the problem instead of solving it for him.

Now as to organization in some of these other directions. There are notions of scientific management talked about these days that I cannot follow with great clearness. For instance where there are three or four professors and instructors in a department, I am not able to see how we are going to have one man devote all of his time to classroom teaching, another to advisory functions and another to the administration department. I am not sure that the author intends that, but it certainly seems to me that, in the average institution represented in this society, each teacher would have to take upon

himself several functions. Furthermore I am not sure that by labelling a man an advisor for the student you are going to get the best results. Now in nearly all of our coëducational institutions we have had some experience with the person known as the advisor of women. For this post we require a woman who would be an advisor anyway, otherwise labelling her as such is useless. One must select a person whom the students would naturally select as an advisor. I am not sure that we are going to be able to direct that phase of organization along the lines of the paper to the full extent advised except in very large institutions.

One point brought out in the discussion of the number of courses interests me particularly. I have had a good deal to do with the accrediting of high schools. It is quite customary in most of the states of the northwestern country for the accrediting colleges to insist that the high schools shall confine their students to about four subjects. At the same time those institutions are often teaching their own students six courses. As the student progresses, his work becomes easier and usually it becomes more effective by reducing rather than increasing the number of courses. And furthermore it seems to me that he can, in these subjects, get new points of view with reference to the fundamental courses. It is not necessary to revise the whole curriculum in order to introduce a new idea or to take advantage of a new discovery. A little conservatism, or a little return to former conditions in connection with the number of courses as well as the number of students, would be desirable.

I would say, in closing, that I think the engineering professor has a much simpler problem in teaching, provided he has correspondingly adequate facilities and an adequately large staff, than the academic teacher. The great defect in academic instruction is the lack of motive to secure good results. Now the engineering professor has a much simpler problem in this respect. We look to our engineering schools to furnish the finest types of educational efficiency that are to be found.

HOW CAN THE COLLEGES AND THE INDUSTRIES COOPERATE?

BY IVY L. LEE,

Executive Assistant, Pennsylvania Railroad Company, Philadelphia, Pa.

You have asked one who is not an engineer to give you suggestions as to how as teachers of engineering you can produce better results. I can, however, possibly qualify for my task in the manner of a candidate for the judiciary in one of our western states, who was urged for election upon the ground that he would make a most excellent judge because he had no preconceived notions of the law.

Though without direct personal experience in either the employment or training of technical men, I have enjoyed the opportunity of frank consultation with many of the higher officials of the railroad system with which I have the honor to be connected. I feel, therefore, that I cannot do better than essay the presentation to you of a composite of the views of these men of wide experience and great breadth of view.

Relation of Theory and Practice.

The college is both a training school and a laboratory. The industries of the world not only look to you to train men who can take up the work of directing and guiding great enterprise, but to a constantly greater extent industries are looking to you to solve their broader problems. When President Taft wanted a man to report on what should be the proper system of charges on the Panama Canal, he sent Prof. Emory R. Johnson, of the University of Pennsylvania, to make the inquiry. Some of the finest work in the study of the transportation question is being done by Prof. W. Z. Ripley, of Harvard. The astonishingly able accounting analyses of Prof. Henry C. Adams have been of priceless value to the Interstate Commerce Commission.

Right here, however, I would direct your attention to the point brought out in a conversation I once had with Mr. W. M. Acworth, the distinguished English railway economist, who, after returning to London a few years ago, from attendance upon a meeting of the American Economic Association, made this observation:

"I was surprised, hearing the college professors discuss the transportation question, to note how little they really knew of it. They understood the theory, but not the practice. And later, discussing the subject with railroad presidents, I was astonished at their lack of breadth. They understood the practice, but few knew the theory."

And that, gentlemen, leads me to the chief thought I wish to present to this gathering. The demand of industry is for men who understand both the practice and the theory.

Faults of Technical Graduates.

Let me be concrete. It is the experience of Pennsylvania Railroad officers that graduates who come to them from technical schools are deficient in three general particulars:

1. Lack of practical experience and judgment.
2. An idea that they are far superior to the rest of mankind; and
3. A certain narrowness of mind, inculcated through a too exclusive attention in college to mathematics and theoretical science, and a too great neglect of those broader subjects, such as political economy, history and general literature.

With your indulgence, therefore, I will make a few suggestions as to how these deficiencies may be met.

How Practical Experience May be Gained.

The question of practical experience might be remedied by the man serving two or three years as a machinist prior to going to a technical institute. Of course, this is not feasible in a large number of cases, and the man must get his actual experience after he starts regularly to work. But the college can implant in his mind certain sound fundamental ideas. A man

who has had a good engineering education and has absorbed commercial ideas will make a good commercial engineer. One who is a theorist and scientific man only, with no commercial ideas, will make a good investigator, and possibly a good man in a test department, especially when engaged in scientific research; but even a good test-department man requires some little idea of business, because test-room questions are not settled on quality alone. The best quality for the same cost is the real question at issue. The man of great value to an industry is he who does not merely attempt to follow a theoretical ideal, but who adapts his theories to the actual limitations of the moment, and secures the best practicable result.

Attitude of the Graduate Toward His Work.

Men leaving technical institutions should be made to have a thorough understanding of the fact that they are necessarily almost completely lacking in a real knowledge of the practical application of the principles they have been studying. If a student can be trained by the time he completes his college course to have real openness of mind, he will be well on his way toward success when he leaves college. Young technically educated men leaving school should, at the start, forget that they are men of scientific training, and tackle work precisely as do other workmen, knowing that when they have mastered that part of their education, the time spent in doing so will not have been wasted.

While it is not expected that technical men entering railroad shops shall have to consume as much time on menial or trivial work as those not possessing such advantages, nevertheless, to regard time spent in the shops as time lost in the pursuit of their true vocation is a very grave mistake, and results in many technical men not being advanced to positions in which they manage other men.

It is of the greatest importance, too, that students be impressed with the human elements in all industrial work, that is, they must realize that whatever their college education may have been, they are of very little real value until they have

acquired something which few colleges teach. Too often young men come from our colleges with the feeling that they know too much to be told anything by men who have not had a college education. By assuming such a stand they close the mouths of men who could and would give them very useful information.

A beginner in the practical end of any line of work should be taught beforehand that college education is not everything, and that results can only be accomplished through other men. Therefore, he must get the viewpoint of other men before he can secure that sympathy from these other men on which his success as a manager will depend. In doing this, he will get much misinformation, which he will know to be such, but this knowledge he should keep to himself. We see all around us men holding the highest positions, who have come up from very small beginnings, with no apparent advantages. Yet we find that these men have their business at their finger tips, because they have been through all of its grades. The feeling that the possession of an education relieves a man from the necessity of going into these details has resulted in many men becoming nothing but technical advisers to carry out the wishes of other men who thoroughly understand the details of their work. Such merely technical advisers never share in the great rewards which come to the men who combine a mastery of both theory and practice.

Importance of Fundamental Principles.

It is of prime necessity, of course, that a man who is trained to practice engineering shall have a good engineering education. Successful men in railway engineering work must necessarily be familiar with the laws of nature, and the fundamentals of mathematics. This information can be obtained, however, outside of technical colleges, and the man who obtains his information in this manner, by the necessarily more concentrated application on his part, is generally a better engineer than a large percentage of college graduates, Many competent judges believe that technical courses in the majority of the colleges lay too much stress on details. If more

time were spent on the study of fundamental principles, it would result in developing more resourceful men. Some of our officers, in advising young men, have suggested to them that they devote their entire time to the study of mathematics, physics, chemistry, English and one foreign language, and not take up any particular branch of engineering. A student who is well grounded in the above studies can take care of any proposition which will come before him. His resourcefulness will be developed by reason of his being compelled to work from principles rather than trying to fit the problem before him to some particular detailed case which he has learned in his engineering course.

Many of our officers hold the view that the best shop work for college men is that which can be obtained during the summer in the various shops where actual work is done, rather than having the time of the student taken up by the more or less imitation shop work that is done at some of the schools. The most valuable part of shop experience to a student is the coming in contact with men and absorbing their experience.

I asked not long ago the man who, I believe, is conceded to be the greatest expert in this country in railway electrification, to tell me what he really learned in college. His reply was, "I am inclined to think that the most valuable asset that I brought out of my college course was the habit of studious application to the job in hand, rather than a finished knowledge of any subject. In the final analysis, the technical student has only time to acquire a fairly good grounding in principles of engineering. The college trained man, however, has an immense advantage, after he obtains some experience, over the non-technical man in being able quickly to grasp the relation between the theory and practice and to apply correct principles to practice.

Adaptation of Men to their Tasks.

I would urge that you not only see to it that students receive a broad general education, but that they be made to see that it is of great importance not to be in too big a hurry to commit themselves to a particular life work. College pro-

fessors can be of great value to their students, and also to industries, by advising men frankly as to their limitations, and also as to their strong qualities. The principles enunciated in Prof. Hugo Münsterberg's remarkable book, "Psychology and Industrial Efficiency," will, I believe, receive more and more application as time goes on.

Young men are frequently placed in positions for which they are entirely unsuited, while if they were moved to other positions more adapted to their make-up, they would often prove successful. Some of the very best men in certain departments in our shops at Altoona can never go higher because there is nothing for them to do in general railroad work. In some of these cases no other men on the road could fill their present positions as well as they do. The only thing for such men to do is to leave the railroad and seek positions with concerns that can afford to pay more for the particular kind of ability which these men possess.

Social Service for College Men.

So much for suggestions as to how colleges can the better equip men for taking their part in building and directing our industries. You have all noticed, however, that this is a day of social service. Never before were so many men being called for to act for the people at large in the control of industry, and particularly transportation. The Interstate Commerce Commission has just advertised for a large number of engineers to assist in the pending federal valuation of railroads. Never did a situation more strikingly illustrate the need for men with practical training. If the proposed valuation is carefully and wisely made, it will do great good. As Mr. Thomas F. Woodlock said, in a most illuminating article in the New York Times Annalist of June 23, "Practical confiscation—partial at least—of property actually invested in railroads will be quite possible by 'valuation' if the public is determined to do it, or if the 'valuers' are permitted to run riot among the technicalities." It is an occasion when practical men are needed, men capable of seeing facts as they are, and not with reference to any theories or past prejudices.

So men are being demanded for work with public service commissions, in colleges as teachers, in University settlement and municipal health work, in city governments, and in all those capacities where men can serve their fellow creatures. This is one of the hopeful signs of our times, but this is a period of great unrest. Many strange economic and political theories are being preached. It is a time when our young men should see that things cannot be always as they should be, but that our duty is to make them as good as we can.

Railroad managers for instance would be delighted to equip every mile of road with automatic block signals, to make every car of all steel, to remove all grade crossings, and otherwise to avail themselves of every device to insure safety. But this cannot be done without the necessary money. So in all things, it is well to "hitch our wagon to a star," but to be sure also that the connecting rope is long and elastic enough to let us keep the wheels on *terra firma*. We cannot go through life on an aeroplane. The manager of every industry would be glad to allow his employes a short work day and to surround them with every comfort and luxury. But here again are limitations which must be regarded and which it is of particular importance to have deeply imbedded in the minds of the men you send out into the world to work and to direct the labor of other men. Amidst all the efforts for social betterment and for adding to the general welfare of man we are forced to realize the old-fashioned doctrine that, in the long run, men can reap only as they sow. I leave with you, then, these lines of Kipling's:

"From forge and farm and mine and bench,
Deck, altar, outpost lone—
Mill, school, battalion, counter, trench,
Rail, senate, sheepfield, throne—

"Creation's cry goes up on high
From age to cheated age;
'Send us the men who do the work
For which they draw the wage.'"

HOW CAN THE COLLEGES AND THE INDUSTRIES COÖPERATE?

BY EDWARD D. SABINE,

Terminal Engineer, New York Central and Hudson River Railroad Company, New York, N. Y.

The subject of coöperation between the colleges and the industries is altogether too great to be treated in all its aspects in one paper, especially by one whose experience has been no broader than that of the writer. Therefore, I shall attempt only to illustrate a few points that have occurred in my own experience as a railroad engineer.

Relation of Railroad and College.

In dealing with the coöperation of the railroad and the college the first idea which presents itself is that the railroad as a unit cannot deal with the college. The principal divisions of the railroad are the construction, operating, traffic and financial departments. These are all coördinated by and subject to the executive. Each of these departments is subdivided. At the present time the principal connection between the college and the railroad is through the engineering division of the construction and operating departments of the railroad.

The writer, having spent his railroad career in engineering and construction, will not attempt to consider the relation of the other departments to the technical school. There is an opportunity for the college-trained man to become useful in this department sooner than anywhere else in the railroad. The opportunities for promotion are great, and it is not necessary that he remain strictly an engineer as has been shown by the careers of the numerous men who have entered railroad service as rodmen and who have attained high executive positions. This is well illustrated in the career of the late Mr. A. J. Cassatt, of the Pennsylvania Railroad lines, who com-

menced service as a rodman and who attained a position worthy of the efforts of any man.

There are several ways in which the connection between the railroad and the engineering school can be broadened. I believe thoroughly that a railroad man should be 'captured' as young as possible and that he should stick to railroading from the very beginning. This, of course, does not mean for a young man just out of college to step immediately into a position of any great responsibilty. The fact that he cannot do so tends to make the young graduate turn to fields where the immediate rewards are larger, although the final goal is not nearly as attractive. The writer believes that one of the best ways of attracting the undergraduate to railroad work is by a system of volunteers.

Volunteers in Railroad Organizations.

The field office under my charge employs on an average of twenty-five men, divided among inspectors, line- and grade-men and clerks. For several summers past one volunteer has been received into this office. His pay has been very small, the idea being that he would receive in experience more than the value of the time which he contributes to the office. This volunteer is called upon to do the work of a regular chain-man, working with different parties and under different conditions, so as to cover the various phases of the work which is handled by the field office. He is required to help the other chain-men to keep the instruments properly cleaned, to do his share of errands and work of this nature. He is also, however, given the opportunity to do some real work and to learn the importance of even the humblest member of an organization who does his work properly and with due regard to the safety of others as well as himself. One young man who thus volunteered for one summer did so well that the following year we were able to use him as a regular inspector. A second found work with another railroad immediately after graduation and the writer has been informed that he has gone ahead faster than the average graduate. It would seem that a sys-

tem could be worked out by which the railroads should take a number of volunteers into their service for the summer months to the advantage of the men, of the schools and of the railroads. Of course, it is absolutely necessary that the men who are picked as volunteers are earnest and thoughtful and are desirous of following railroad work after graduation.

Excursions for Students.

This system of volunteers can well be supplemented by arranging excursions for the undergraduates to view various pieces of construction work. These excursions should not be handled as if the undergraduates were consulting engineers and called upon to report the progress of a job, but rather to give them a conception of the actual meaning of engineering work and of the responsibility which falls upon every engineer who has anything to do with construction. The volunteers should come from schools near the location of the work upon which they are employed, so that excursions can be handled from the same schools, and so that these excursions can be supplemented by lectures by the men in actual charge of the work. These lectures should, preferably, be given previous to the excursions, in order to give the students an idea of what they are expected to see and what to observe. This will also give the engineering officials an opportunity to get acquainted with the rising generation, so that as openings come in their departments they will have men lined up who can fill them. At the same time, the contact between the instructors and the men who are actually working cannot help but be beneficial to all concerned.

Need for Letter-writing Ability.

To my mind, one of the most discouraging features of present-day technical training is the difficulty of getting a clear and definite letter of application from the average recent graduate. I have expressed this to various instructors in technical schools and suggested that students be required to

write letters of application, which the instructors could criticize, and have offered to go over some myself and explain in what ways these letters were deficient. My remarks have always been listened to, but my offer has never been accepted. It would seem as though the schools should take advantage of a concrete suggestion, or at least show the man making the suggestion the courtesy of explaining why it is not feasible to adopt it, which brings me to my second suggestion and that is, that the way to coöperate is to coöperate.

Keeping the Teacher Inspired.

There is a great prejudice among many men active in industrial life against the college professor. This is due chiefly to the old-time notion that a professor is a dried-up man who works in a laboratory and takes no interest in actual work. This impression is fostered by such an incident as I have related. Those who come in contact with the really great instructors know better, but the younger men who do the detail work of instruction do not make as good an impression. Let these young men come into the shops and out on the job and see the men who are doing the work. Let the instructor who graduated five years ago go and confer with his classmate who is inspecting masonry on a big dam, and in turn let the inspector drop into the classroom now and then. Assure us who are in the work that we are welcome and we will come. We will be glad to call on you the instructors and rub elbows with you. We alumni want to help make the years of college of the greatest value to the students, but we must feel that we are welcome or we shall stay away.

Discussion.

Dean F. L. Bishop: In Pittsburgh we are located exceptionally well for studying railroad work. We have prepared the outline of a course in mechanical railway engineering, under the direction of Mr. D. F. Crawford, general superintendent of motive power of the Pennsylvania lines, who has devoted a

great deal of time to its development. The young men who take this work will do coöperative work, not only with the Pennsylvania lines, but with the Baltimore & Ohio and the Lake Shore and various other lines. This course will, I think, be somewhat different from the railroad courses offered in other institutions, in that it represents exactly a railroad man's idea of what kind of education a young man should have. Mr. Crawford has twelve thousand men under him, including a great many engineering graduates, so that he knows what is needed in the way of preparation for railroad work.

Professor F. W. Sperr: It seems to me absurd, with our age and experience, to seriously consider that a youngster of between the ages of eighteen and twenty-two can get a finished education in any course. But what should he know? I asked one of our most successful mining managers a few years ago the following question: "After your experience as a college graduate in mining engineering, as a professor of mining engineering, as a practicing mining engineer and as a manager of one of the largest mines in the country, what do you think that young fellows contemplating going into the mining business should be taught?" He unhesitatingly answered "To think." He said that when he was in college he rowed and he *thought* rowing, but that while he studied physics and mining subjects, he did not *think* them. After he got out, however, he had to do some thinking. And he has to continue to think.

At the College of Mines we have a field course in surveying, including some railroad surveying, enough so that the miners can, for example, lay a spur track. Yet I always tell the students that if they could understand the principles from books without using instruments in the field we should not go to the expense of giving them the summer course in surveying. In all of our work our problem should be to teach the young men to think and, if I caught the drift of the paper correctly, that seems to be just the difficulty with the college graduate, he has not learned to think of the things that he has got to do. He

has learned to think in football, rowing, baseball and other games, but not in the things that he has got to do.

Dean C. M. Woodward: I enjoyed Mr. Lee's paper and consider that the third part is a splendid answer to the question raised in second. He showed exactly how the engineering graduate can avoid the so-called "big-head." He should be taught not the commercial details of the day but the everlasting principles which will be the same to-morrow, next year, a hundred years hence. I attribute the "big-head" that young graduates often have to the fact that someone has tried to teach them exactly how to do business to-day. He has tried to teach them the prices of material, the price of labor and just how to manage it, and the young men go out thinking they know all about it. Now these are the changeable things. They do not last. I have observed that when a student has been taught the permanent things he has said very properly to a prospective employer, "I don't know how you manage your business, nor the details of your shop, I am here and ready to learn." The open mind is as important as the trained mind.

The world is coming to estimate rightly the man who can think and solve a problem, which has never been solved before, by the application of the everlasting principles of the materials and forces of nature and humanity. It ranks him higher and higher in the social scale. Last year it gave a high degree of honor to a civil engineer, an honor and a degree which I do not think they ever gave before. There was a man that could think, and all through the country they are now consulting engineers who, if they understand general principles and laws, can apply themselves to new problems.

Professor B. L. Newkirk: This matter of the conceit of the new graduates lies a good deal deeper than any training which we give them. Whenever this matter comes up I am reminded of a conversation in which I took part something over fifteen years ago. I was serving as an undergraduate assistant to an officer of the state. There were one or two other assistants in the same office. His method of training was sometimes vigorous, almost harsh. It happened that one of the

other assistants had offended at a particular time, and I was getting the benefit of the consequent vexation, because the other man did not happen to be present. My employer said, "I never had an assistant whom I did not have to cuff the conceit out of." Well, I didn't know just what to say, but I asked him if he had never tried to get assistants who were not conceited. "No," he replied, "I don't want them, they are not worth the powder to blow them up." It seems to me that in the very nature of humanity the young fellows are conceited, and I don't know but that it is a good thing. It is one step in their progress and if employers were to employ young men who were not conceited, they would come to the same conclusion as did this man, that such are not the kind of fellows they want.

There is another phase to this question. At a meeting of this society held in New York a few years ago Mr. F. W. Taylor said that there was a feeling that the larger companies which took in the young graduates as apprentices were exploiting them. I have talked with many of our young men and find that the companies, large and small, want to take them in for, say, fifteen cents an hour for an apprenticeship course. When you inquire what education it is proposed to give them, how they are to be transferred from one branch to another, and what is to be offered to keep them, the answer is discouraging. Thus the young man when he goes out has to be in a state of mind to enable him to defend himself from the people who are glad to get his services for a very moderate compensation.

Professor P. F. Walker: I feel that this matter of coöperation is an extremely important one and that we who are in the teaching work need the coöperation of the industries. On the other hand the industries also can well afford to secure real coöperation. In my course in mechanical engineering we have required that, during the summer vacation usually before the junior year, the students shall get perhaps two months of practical experience. We insist that the men go out into commercial work rather than work in our own shops. There has

not been a single student for whom we could not find commercial work, although it has not always been the line of work best adapted to them. I was disappointed this spring in receiving a reply from one of our large concerns, which a few years ago took two of our juniors, stating that they had given up the practice of taking men before they had graduated on account of the difficulty experienced in giving them proper work and arranging afterwards for doing anything with them. I was not asking that this concern should take any men with any assurance for the future but they seemed to feel that there was difficulty in taking men on for a few months. I believe that the industries can well afford to sacrifice a little in this direction. I know that we sometimes run against difficulty resulting from the control exercised by the unions, but at the same time there are not very many plants and industries which are not hampered in this way. I believe that there is a real way in which the industries can coöperate with the schools in helping out by furnishing work and thus really giving the men something as a basis for thinking.

I was very much impressed with what has been said regarding teaching students to think. There is nothing better for this purpose than the experience gained in actual work. Then when the men come back and go into other more advanced work, they have the viewpoint which they obtained outside. This serves to stimulate their thought and to greatly enlarge their mental horizon.

Dean F. L. Bishop: This matter of conceit really does exist, but it probably is greatly magnified. During the past few months I ran across two cases which are of sufficient interest to recount. One man was a graduate from a famous institution in the East who was assigned some very good work. When it came time to change him, as he had done so well, it was suggested that he go to a certain department and do some special outside reading under the direction of the young man in charge of the department and that he then work into that department. He asked: "Where did the man who is at the head of that department graduate?" The chief engineer said,

"From Cornell, why?" "Well," he said, "You don't suppose that a Cornell graduate can teach me anything, do you?" That story has circulated through the works ever since and everyone who knows about the conceit of this one man contends that this is what you may expect from a college graduate. The other case was this. A young man, who had received very high honors in his institution, was taken on in a shop with the idea that he would develop much faster than some of the others. He was assigned a certain piece of work with the expectation that he would stay on it at least three months, as it was the first time he had ever worked. At the end of two weeks he came back to the head of the department and asked him if he might be changed, that he thought he had learned all there was about that work. And the head of the department said, "All right, we will change you. To what department do you want to go?" On his replying he was sent to the desired department but returned in about ten days having learned everything there and desiring to be changed again. This was repeated until finally the chief engineer got tired of the process and gave instructions that the young man should be kept in one department at least six months. Not liking this treatment the apprentice finally took the matter over the heads of his immediate superiors to the vice-president of the company, thus antagonizing those who could have helped him most. As a result he has made very poor progress largely on account of his mental attitude toward his work.

Mr. A. T. Baldwin: I am particularly interested in the problem of education because I have four or five children growing up and I am naturally after an education for my boys in the best universities in the country. The problem of education has appealed to me from the point-of-view of manufacturing. From the manufacturer's point-of-view do you not take the raw material in the shape of boys who have graduated from the high schools, and endeavor to give them the greatest amount of theory in the shortest possible time? Should not the educator do what the manufacturer is doing at the present time? The latter expects more from his gas engines, his

boilers, his machine tools and he gets it. Can't we get more out of the human engine than we are getting, in a shorter space of time? I believe it is proper to endeavor to do that. It seems to me the right direction in which to work is in the line of putting more energy and better work into a shorter period of time upon our raw material. We cannot always select this raw material, but the college will naturally get the best results when it can select its raw material.

While I do not believe that a student should be conceited, he can have confidence in himself. The most successful men in the country today are the ones who have confidence in their own ability. They have not the "big-head," conceit, but they do have self-confidence and I would have the educators of the country encourage this spirit in their students.

Mr. J. W. Dietz: As a representative of a large employer of college men I take pleasure in telling something of an organized effort to give college graduates an opportunity to learn thoroughly the fundamentals of our business. Each year the vice-president appoints an educational committee made up of six men representing the three main branches of the business, that is, the commercial, the engineering and the manufacturing branches. The committee members at this time in the manufacturing branch happen to be the superintendents of our two largest plants, in one of which telephone apparatus is manufactured and in the other, the electric cables. The two men representing the commercial side of the work are our sales manager at Chicago and our telephone sales manager at New York. From the engineering department, the assistant chief engineer and the chief equipment engineer are members of the committee. The committee meets regularly and, as an advisory committee, directs the organization of the educational courses. The manager of the educational department is responsible to the head of the committee and, therefore, directly to the vice-president. The educational department's work has the prime object of giving a broad fundamental training for our business.

The training work is accomplished in three broad ways.

First, the students are given an opportunity for careful and systematic observation which is definitely scheduled under the advisement of this committee and the manager of the educational department. Assignments for this purpose include the entire organization, as many as thirty-five different departments being covered in one year's work. The second method of instruction is by actual practice, in no sense in an effort to get productive work from the men at a low rate of wages. Carefully-prepared statistics have been kept for a number of years and we find from the actual figures that the men are not able to earn the full salary which is paid them. The condition in which we wish to have them is that of a sponge, simply to absorb by observing processes. We believe, however, that it is well worth while for them to get the actual practice and contact with the workmen, hence we value this second part of the work.

The third method of instruction is by means of class-room and lecture work. The men are required to make definite, formal reports of the work done in their departments, and these are turned in each week, showing what has been done each day. Each man is thus taught to value his own time and the company's time. During the entire educational period, the department heads and others give lectures on their specialties, which the men are required to attend. These are given in the company's time and, therefore, no sacrifice of time or earnings on the part of the men is required. This policy we find to be amply justified in a business of the extent of ours.

Our company believes in college inspection trips. During the past twelve months more than four hundred college men have visited our plant in connection with these trips. We have tried to coöperate in a definitely systematic way, and to give our visitors intelligent, trained guides who can answer their questions. We want the visitors to have ample time to see the work thoroughly. We try to coöperate with educational institutions also through the visits of our representatives to the various colleges to give first-hand information as to the nature of our business and in an effort to enable stu-

dents to decide intelligently as to whether or not our work is such as to interest them permanently after graduation. We also believe in summer employment. I have a bit of testimony from a non-college man who employs a great many people in installation work. He told me just a few days ago that his foremen, whose work has to do with the installation of telephone exchanges, are glad to have college men come with them for the summer. He says it is somewhat of a handicap to have the men leave so soon but his attitude is evident from the fact that he employed last summer fifty or more men.

I believe that the educational committee realizes that the college men, by having this broad foundation period of training in our business, are much more able to adapt themselves promptly to their special assignments on the completion of the work. I have endeavored to outline the definitely-organized way which has been developed for coöperating with the college men who are entering the employ of the Western Electric Co.

Director W. B. Russell: I agree with Mr. Lee's conclusion. It would appear from the paper and from the discussion that the success or failure of the technical graduate is largely dependent on his particular viewpoint, and on his state of mind. Just here is where the technical-school professor can have a decided and immediate influence. I once ran across a graduate of one of the technical schools who after being six months with one of the railroads in the locomotive department thought that all of the locomotives should be re-designed and he was perfectly frank to tell everybody so. He was as bright a fellow as I have met and undoubtedly he is making good somewhere by this time. It was a matter of viewpoint entirely.

Then, again, there is a danger which this paper has brought out, namely that we may be a little too efficient in our engineering education. It is a fine thing to be an engineer, and if we tell the student this too forcibly he will think that engineering is all there is to life. The result is, perhaps, that he becomes a mechanical engineer for a railroad, getting perhaps four or five thousand dollars salary, while the superintendent of motive power over him, who is not a mechanical

engineer and who has not nearly his ability, is getting perhaps twice that salary. The engineer is so in love with engineering that he fails to see the opportunity to get the bigger job with more influence and more pay.

Dean C. H. Crouch: I am pleased to note the change in attitude on the part of the large industries toward the technical graduates during the past twenty or twenty-five years. I feel, however, that the colleges cannot give all of the training that these companies want. It is quite necessary I believe for the men to rub elbows with the mechanics and laboring men before they can be competent to be placed over other men and become successful superintendents. In the shops they get a training that we cannot give in the colleges, except in a partial way. There is no way that I know of by which our schools can give the training that the industries can give in that line. Men come into contact with various phases of human nature in commercial plants and I believe manufacturing industries have excellent facilities for taking out the conceit about which we have heard so much, if they only know how to do it.

I was impressed by a statement made by one who employs a large number of technical graduates in response to my inquiry as to the points in which our graduates are deficient. He said that their deficiencies result not from lack of technical training but rather from an unwillingness to work and to do menial things. Hence one of the first things he had to do with them was to "take the conceit out of them." There will always be the exceptional student who is somewhat conceited, but there is no difficulty in taking the conceit out of him, and after that he is likely to be a valuable man.

Mr. Lee: I have been very much edified by the remarks that have been made and can multiply instances to corroborate the points brought out. The Pennsylvania Railroad has had to do with many men who thought at the outset that they could tell us how to run a railroad. Every freeborn American thinks that there are two things which he knows how to do very much better than they are being done by the people who do them. One of them is how to run a newspaper and the other

is how to run a railroad. This is particularly the case with your college graduates who are taking special work in transportation. An instance that comes to my mind was in connection with a Harvard man. Harvard has a graduate school of business administration in which they have some very interesting and elaborate courses in transportation, very well conducted indeed. One of our vice-presidents made an address at Harvard a few years ago in which he told of the demands of the railroads for college men. He told the class of the practice of the Pennsylvania Railroad of not taking any man into its service in what we may call the rank of commissioned officer, or in line for promotion to that rank, who is not a college graduate. Of course when he went back to work he got a great many applications for jobs. These were sifted over, as the opportunities were limited, and we picked out the man whom we thought would make good in the traffic department, that is, in the solicitation and handling of freight traffic. He was assigned to work on one of the piers in New York, the plan being to make him familiar with the rates, to put him into close contact with the public, to make him actually receive the freight from the draymen, to way bill the freight and to see that it got started on its journey to the consignee properly. This man was to work at the job for about six months and we were going to put him at something else. After he worked there about three weeks he wrote a letter to the vice-president, disregarding his immediate employer, and advised him that he was thoroughly familiar with this work and would now like to be considered an applicant for the position of assistant to one of the vice-presidents. Obviously he did not "last long" with the Pennsylvania Railroad. While I sympathize with the viewpoint of the gentlemen who believed in inculcating confidence, yet confidence in one's fundamental ability is different from having confidence in the fact that your technical adaptation of that ability makes you competent to go ahead and tell other people how to run their business.

ADDITIONS TO THE EQUIPMENT OF THE RAILWAY ENGINEERING DEPARTMENT OF THE UNIVERSITY OF ILLINOIS.

BY EDWARD C. SCHMIDT,

Professor of Railway Engineering, University of Illinois.

Seven years ago, in recognition of the importance of the railway interests and the complexity of railway problems, the President and Trustees of the University of Illinois determined to offer courses specifically adapted to the needs of those expecting to enter railway service. The magnitude of the railway industry of the state and the general relation of Illinois to the railways of the middle west make it appropriate that the University of Illinois should have taken the initiative in a movement for special technical training for railway work, and that it should have been the first institution to establish a comprehensive plan for technical training for all departments of railway service.

As a result of the consideration given this plan in 1906, there was established then a new department of railway engineering, offering three courses in railway engineering. At the same time provision was made in the department of economics for administering courses in railway traffic and accounting and in railway transportation. To coördinate these courses and to facilitate their general administration, all five courses were grouped in the School of Railway Engineering and Administration. Since its establishment, the railway engineering department has administered courses in railway civil engineering, railway electrical engineering and railway mechanical engineering, designed to prepare students for service in the engineering and motive power departments of steam and electric railways. These courses differ from the courses in civil, electrical, and mechanical engineering by the

inclusion, in the third and fourth years, of special courses dealing with the design and operation of railway equipment; and they bear to the regular courses a relation similar to that borne by such a course as that in municipal and sanitary engineering to the regular course in civil engineering. The course in railway mechanical engineering, for example, differs from the course in mechanical engineering by the introduction

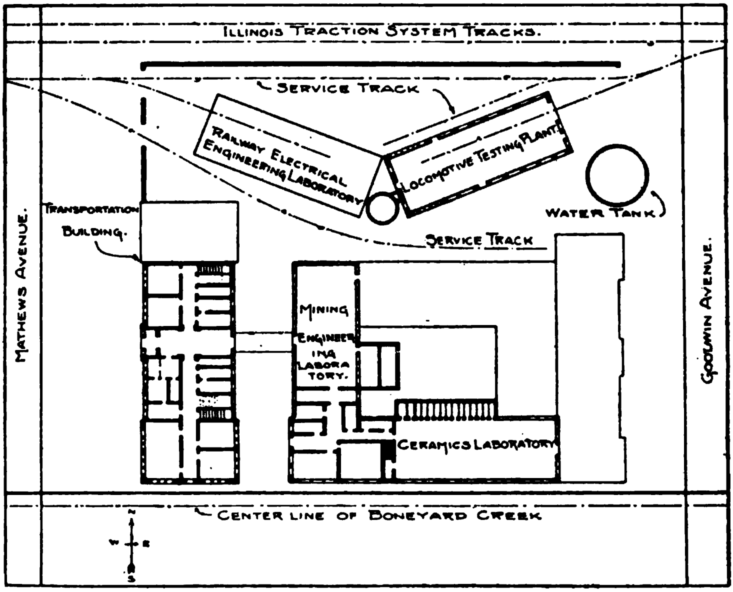


Fig. 1. Ground Plan of the New Buildings in the Transportation Group.

of 27 semester hours' work in railway courses, such as locomotive and car design, and locomotive performance.

Practically all the graduates of this department have entered railway service. A few are employed in companies which manufacture railway supplies. The demand for these courses has amply warranted their establishment and the university administration has felt encouraged recently to make notable additions to the equipment of the railway engineering

department in the form of a new Transportation Building and a Locomotive Laboratory. These buildings are part of the group shown in Fig. 1.

THE TRANSPORTATION BUILDING.

The Transportation Building is the main building of this group. It has been occupied since September of last year. The plans provided for a building 185 ft. long and 65 ft. wide. At present 45 ft. at the north end of the building are omitted,

FIG. 2. The Transportation Building.

since at the time construction was started the land upon which this portion will finally stand was not owned by the University. The building has three stories and is built of red brick with Bedford limestone trimmings. The construction is fireproof, consisting of a tile-protected steel skeleton, brick walls, tile partitions, and concrete floors. The roof is of reinforced concrete covered with slate. The interior finish and all furniture is of oak. The corridors of the first story have tile

floors. All other flooring throughout the building is of maple. The first and second stories contain class rooms, drafting rooms, a library, a small auditorium, several small laboratories, and offices, all arranged as indicated in the plan shown in Fig. 1. The third floor contains six large drafting rooms, five small offices and a blue-print room. Although it is planned to be occupied eventually by the railway engineering

FIG. 3. The Main Entrance to the Transportation Building.

department alone, the building at present is occupied by the departments of railway engineering, mining engineering, and general engineering drawing.

THE LOCOMOTIVE TESTING PLANT.

The locomotive testing plant is the fourth laboratory of its kind now in service in this country. There are two others abroad. Its fundamental purpose is to permit locomotives to be so mounted as to enable their boilers and engines to be operated while the locomotive as a whole remains stationary,

thus permitting the same degree of refinement in the measurement of all elements of their performance as may be attained in tests of ordinary stationary boiler and engine plants. This is accomplished by providing for the support of the locomotive driving wheels a series of wheels and axles which rest in bearings carried on a foundation so designed as to permit the position of the supporting wheels to be adjusted to correspond with the spacing of the drivers. The driving wheels of the

FIG. 4. The Rear End of the Testing Pit. This view shows the removable track, the supporting wheels, the bearings, and the brakes in position for testing a consolidation locomotive.

locomotive rest directly on these supporting wheels which play the part ordinarily taken by the rails. The rails run backward, as it were, under a stationary locomotive. To absorb the power of the locomotive, brakes are provided at each end of each of the axles which carry the supporting wheels.

Upon this supporting mechanism the locomotive with the tender removed is backed until its drivers are in proper position. In this operation it runs on its driving wheel flanges over a track which is subsequently removed. Thus supported, it is secured by a drawbar to a dynamometer which not only measures the tractive effort developed, but also maintains the locomotive in its proper position on the supporting wheels. The supporting mechanism is shown in Fig. 4 arranged for the reception of a consolidation locomotive. The dynamometer there appears at the extreme rear. The supporting wheels appear close to the removable track. In this plant the supporting wheels, 52 in. in diameter, are carried on 11 in. heat-treated carbon steel axles, which run in $9\frac{1}{2} \times 20$ in. bearings. Alden brakes $47\frac{1}{2}$ in. in diameter, each provided with three discs, absorb the power developed. The dynamometer, which is of the Emery type, has a capacity of 125,000 pounds. All this mechanism is carried on a reinforced concrete foundation 93 feet long, 12 feet wide, and varying in thickness from $3\frac{1}{2}$ to 5 feet. Supported as here described, the locomotive may be run at any speed and under any load; and for purposes of testing there remain to be provided only the means for measuring the coal and water consumption, and for making the other ordinary measurements necessary in any boiler and engine test. It would be superfluous to describe for the members of this society such auxiliary equipment. The general arrangement of the apparatus is shown in Fig. 5.

In a locomotive test it is important to determine the amount of the partially consumed fuel which escapes from the locomotive stack. Means for determining this fuel loss have been embodied in this plant in the system which provides for the disposal of the gases and exhaust steam. This system will be most easily understood by referring to Fig. 5 and following there the course of the exhaust gases as they emerge from the locomotive stack. They are discharged thence into a steel exhaust elbow which carries the gases up and over to the center of the building, where they are received in a horizontal duct running through the center of the roof trusses.

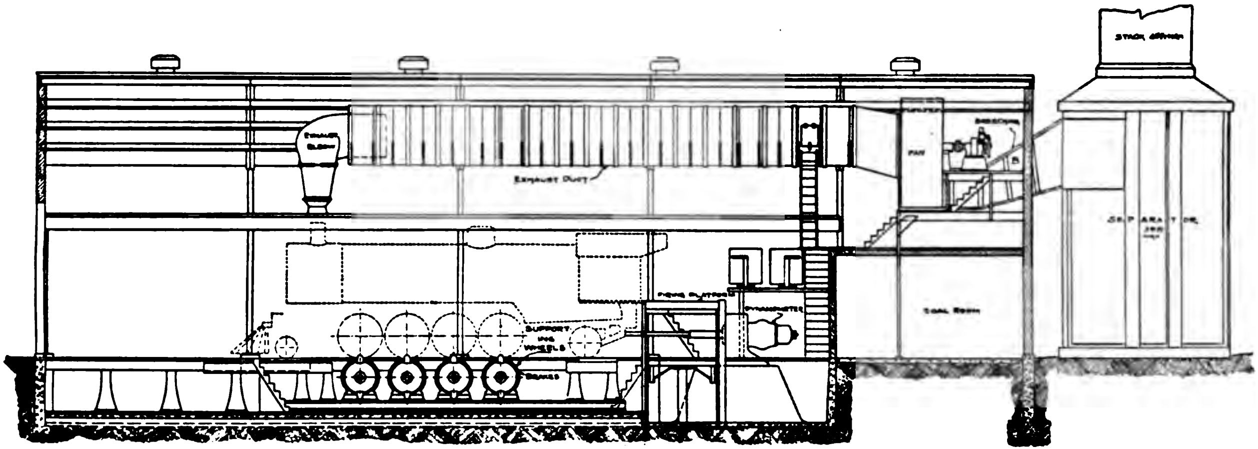


FIG. 5. A Longitudinal Section through the Laboratory.

The gases are drawn through this elbow and duct by an exhaust fan, located near the roof at the rear end of the building. The heaviest cinders are dropped in the duct, but the velocity within it is such that all but the heaviest particles of solid matter are carried on through the fan. Whatever does accumulate here is removed through traps provided in the bottom of the duct, and weighed. From the fan the gases and the remaining solid matter are passed through a breeching or flue to a cinder separator located without the building and below the base of the stack. This separator is similar in design to those used in cement works or wood working mills. It is a cylindrical chamber 18 feet in diameter and 36 feet high, closed at the bottom by a conical hopper. From the top of the separator there hangs into this cylindrical space a smaller cylinder 8½ feet in diameter and about 15 feet long, which forms virtually a continuation of the stack within the separator space. The cinder laden gases entering the separator are obliged to pass downward and out to the stack through the mouth of the sleeve. In so doing they are given a whirling motion which causes the cinders to move toward the wall along which they drop to the hopper below. The cinders collecting at the bottom of the hopper are drawn off and weighed. This separator is surmounted by a 45 foot radial brick stack from which the gases are finally discharged 81 feet from the ground.

The corrosive nature of the mixture of exhaust gas and steam has made it necessary to avoid the use of metal throughout this exhaust system. The exhaust elbow within the building necessarily has been made of steel, and will need occasionally to be renewed. The duct, however, is of asbestos board ("Transite") which will resist corrosion. It is 7 feet in diameter, and made up of separate sections so that its length may be varied. The fan has a runner 6 feet in diameter, and will pass, at maximum speed, 140,000 cubic feet of gas per minute. The breeching between the fan and the separator is built of transite, and has a minimum cross-sectional area of about 24 square feet. The outer shell of the separator is

built of reinforced concrete. To protect the shell from corrosion, it is lined throughout with a hard-burnt red brick. Between this lining and the shell is a 2-in. air space to act as an insulator to protect the shell from undue heating. The inside sleeve and hopper are both built of reinforced concrete. The stack itself is unlined, but is laid up in acid-proof cement. This whole system not only permits the collection of all solid matter, but it also disposes of the smoke high enough above ground so that it is unobjectionable; and it acts at the same time as a muffler to reduce the noise from the locomotive stack

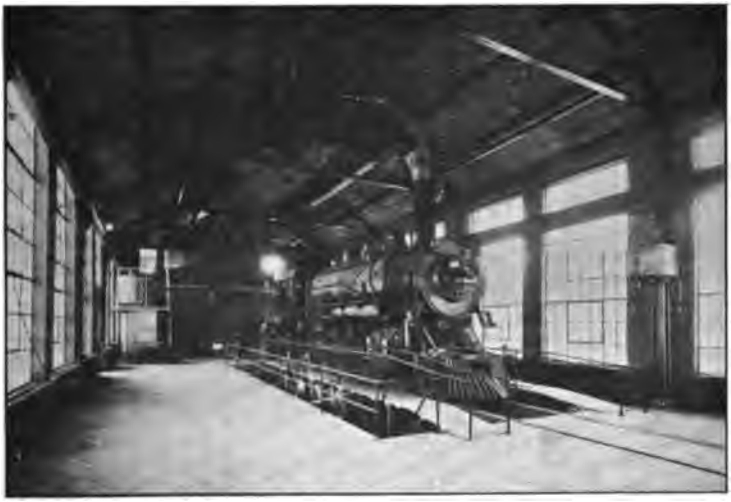


FIG. 6. The Interior of the Locomotive Laboratory.

discharge. The main features of the building which houses this equipment are shown in Figs. 5 and 6. It is 40 feet wide and 115 feet long, with a height under the roof trusses of 22 feet. A basement extends throughout all but 22 feet of its length. The construction is fireproof throughout. The walls are laid up both inside and out with red faced brick, the roof is of reinforced concrete covered with slate, and all floors are of reinforced concrete also. All portions of the building, ex-

cept the space occupied by the coal room in the west end, are served by a 10-ton traveling crane.

The plant has been designed throughout so that it can receive for test the largest locomotives even of the Mallet type. At the same time all the equipment and the building itself have in size and capacity sufficient margin to allow for a very considerable increase in the size and weight and power of locomotives, before a point is reached when new designs will

FIG. 7. Steam Railway Test Car. This car contains apparatus for measuring the tractive effort of locomotives and for studying on the road other elements of locomotive performance and train resistance.

exceed the capacity of the plant. It is not a part of our plan to own a locomotive for service in this laboratory. The whole plant has been designed with the intention to test new designs as they appear, in the confidence that the railways and builders would be willing to keep upon the plant locomotives of recent design, about whose performance all railway officials

desire information; and we have proceeded in this plan with very generous assurance from those interested that we should not be disappointed in this expectation. The first locomotive to be tested is one of the consolidation type owned by the Illinois Central Railroad. It was received at the laboratory in April and is now in process of being tested. This locomotive uses saturated steam and has no unusual features in

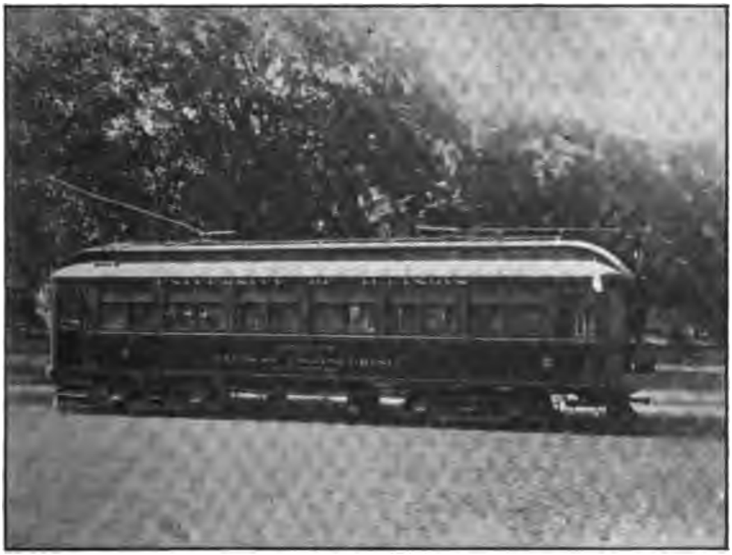


FIG. 8. Electric Railway Test Car. This car is equipped with apparatus for recording power consumption and for determining rail bond resistance on electric railways.

design. In general design and in size it is typical of the majority of modern American freight locomotives. It is the intention of the owners later to equip locomotives of this class with superheaters, and it is expected that the results of the tests will therefore not only add to the rather meager body of information now available concerning the performance of modern saturated steam locomotives; but that they will furnish also a basis of comparison for tests of locomotives using superheated steam.

Railway Electrical Engineering Laboratory.

The only special laboratory equipment thus far owned by the railway department for carrying on the work in railway electrical engineering is the test car shown in Fig. 8. This is a specially designed 30-ton car equipped with apparatus to record such elements of performance as current, voltage, speed, time, distance, and location. It is also provided with apparatus for measuring and recording rail-bond resistance. Other laboratory work of the department has been carried on in the laboratories of the department of electrical engineering.

The Trustees of the University have, however, recently made an appropriation for the erection of a railway electrical laboratory which is now in process of being designed. This will be a companion building to the locomotive laboratory, with respect to which it will be symmetrically located, as shown in the plan in Fig. 1. It is to be a one-story building 42 ft. wide by 115 ft. long, and in general design will be similar to the locomotive laboratory. A space 30 by 40 feet at one end will be reserved for the installation of sub-station equipment, leaving a working laboratory space 40 by 85 feet. This main laboratory floor will accommodate the larger laboratory equipment and in addition will provide place for a brake-shoe testing machine and an air-brake demonstration rack now housed elsewhere. Along one side of this main floor there will be provided a track and pit for the test car above referred to, and along the other side there will be a gallery for the installation of smaller apparatus. A basement will extend under all this portion of the building. The building is to be of brick and reinforced concrete and of fire-proof construction. Like the locomotive laboratory it will be served by tracks leading from the adjacent main line of the Illinois Traction System.

IDEALS OF COLLEGE LABORATORY CONSTRUCTION.

BY C. RUSS RICHARDS,

Professor of Mechanical Engineering, The University of Illinois.

It is, or it should be, the purpose and the function of the engineering laboratory to illuminate the work of the classroom through the verification of physical laws and the determination of the limitations of pure theory; to present to the student the several instruments of the engineer and to familiarize him with their use and care; to stimulate his practical instincts through the handling and testing of machinery of all kinds, and to develop in him some technique in the conduct of experimental investigations; and, finally, to encourage scientific research through which the extent of human knowledge may be increased.

If we accept these ideals of the functions of the engineering laboratory, it must be realized that the construction and equipment of such laboratories is a serious business, not to be undertaken hastily, or without careful consideration of the needs to be served, and it should be realized further, that those who are responsible for such work must be prepared to drop other interests and give their undivided attention to the project for a long period of time, for years if necessary.

An inspection of many of the engineering colleges of the country leads me to the belief that though many engineering laboratories have been built, few have been designed. Given adequate funds, anyone can erect buildings and buy machinery and other apparatus to be placed therein, but everyone will not, by this process, produce real laboratories approaching the highest ideals of service, convenience and adaptability.

Evolution of the Laboratory.

As a rule our engineering laboratories have been slowly developed from the most meager beginnings, often in quarters illy adapted for laboratory or any other purposes, and growing in this haphazard fashion made necessary by inadequate funds and lack of appreciation and interest on the part of college officials. Under such conditions of growth, there can be no adherence to definite plans of development, even when such plans have been prepared. It is small wonder, then, that we find so large a number of laboratories which are illy lighted, poorly ventilated and with few conveniences for work, containing a conglomeration of apparatus in various stages of decrepitude or obsolescence, placed without any apparent thought or system and presenting an appearance so unattractive that a student must indeed be an enthusiast if he receives any inspiration from the work done therein.

What Makes a Good Laboratory?

It is difficult, if not impossible, to define the differences between a good laboratory and a bad one. They are not alone in the building, although that is usually of primary importance, nor in the equipment, but rather in the evidence of systematic arrangement of apparatus and its preparation for experimental work, and in the painstaking and intelligent design of the innumerable details, both of building and equipment, which add so greatly to the convenient use of the laboratory. In other words, it is the evidences of the work of the man of ideas and of ideals which principally distinguishes the good from the mediocre in laboratory construction.

In the design of laboratory buildings it is unlikely that there will ever be a standard type which will be recognized as ideal under all conditions. The peculiar uses to which the building is to be put, local conditions of site and the personal idiosyncrasies of the designer will determine the style and arrangement of the structure. Ideals are evolved by the slow process of evolution and as yet we have made too little progress in the development of laboratory construction to fully realize what constitutes perfection.

Laboratory Architecture.

The art of the architect and of the architectural engineer has made wonderful advances during recent years and we have become accustomed now to the conveniently-designed and beautifully-finished buildings erected for all kinds of business and public purposes. It has been proved that the extensive use of marble, enameled brick or tile, and other expensive materials, which was at first thought to be an extravagance, is in reality a real economy due to decreased maintenance costs. These standards set by office- and business-building designs are rapidly influencing the design of buildings erected for other purposes, even in the industries. Factories are now built with the most careful attention to the details of lighting, heating, ventilation, and finish; many modern power houses are models of design in convenience and architectural beauty and finish. College buildings are now frequently built with reference to these modern standards, rather than with the idea of securing a maximum of room with a minimum of cost. It would seem, then, that it is not unreasonable to demand that engineering-laboratory buildings conform to the standards of excellence in exterior and interior design and finish now recognized. Without doubt the psychological and educational influences resulting from well-lighted, well-ventilated, well-designed, clean and attractive laboratories are worth many times the difference in cost between good and cheap types of construction. We can hardly expect to arouse a tremendous enthusiasm, either in the student or his instructor, for work which must be performed in dingy and dirty quarters. Where such conditions exist there is danger that invidious comparisons will be made between the work of the non-technical and the technical student which may handicap the larger development of the latter.

Ideal Laboratory Buildings.

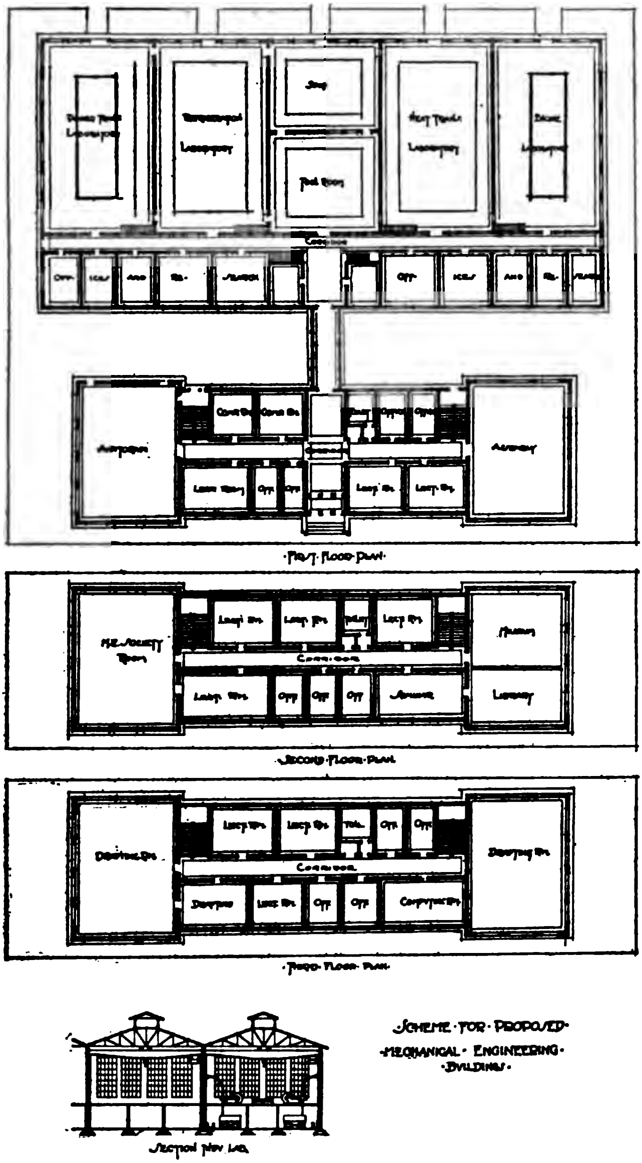
Wherever practicable engineering laboratories should, in my opinion, be one-story buildings with high basements, and with monitor-type roofs to provide proper ventilation and light.

The walls should preferably be of brick, faced on the interior with light buff-colored pressed brick with an enameled-brick wainscoting six or eight feet above the main floor level. The main floors should be of reinforced concrete, carried by steel beams and columns, designed for a live load of not less than three hundred pounds per square foot, well finished on the surface and painted with an approved cement floor paint to prevent the formation of cement dust and the absorption of oil. The roof trusses should be of steel with a light concrete roof supporting a covering of slate or tile. Spanning each room there should be a traveling crane of sufficient capacity to safely handle the apparatus installed.

With such floor construction as described, practically all of the machinery installed on the main floor will require no foundations to the ground. Hollow foundation walls may be needed for apparatus of unusual weight, or where excessive vibration results from the operation of a machine, but steam and gas engines of the usual laboratory sizes will need no extra support. All auxiliary apparatus, such as condensers, piping, etc., can be suitably located in the basement. To facilitate communication between the two floors, an open "well" may be constructed down the center of the main floor.

The width of the laboratory or succession of laboratories, if several be joined together as would normally be done, should rarely be less than sixty feet, unless special conditions demand another dimension. The length of the rooms or "bays" may be of any dimension and the building should be so located as to permit of ready expansion at one end.

The window area provided should be as large as the style of construction will permit, some of the newly patented steel frames and sash with prism glass being probably best adapted to such buildings. It is rare that too much light is admitted and in most existing structures there is an altogether insufficient amount. Not only should all the daylight possible be admitted, but particular attention must be paid to the problem of artificial lighting to permit satisfactory work to



STUDY FOR A NEW LABORATORY FOR THE UNIVERSITY OF ILLINOIS.

be done on gloomy days or at night. Whatever system of lighting is adopted, it should give a uniform illumination of not less than three foot-candles at the floor level.

Since, ordinarily, large quantities of water are used in the laboratory, ample provisions for its handling and disposal must be made. If large volumes of water must be accurately measured, properly designed concrete flumes with weirs, or large measuring cisterns should be constructed as an integral part of the building. Conveniences for handling water in engine laboratories, for instance, are frequently overlooked in the original design of the building, and their later installation is apt to be unsatisfactory.

Adjoining each main laboratory there should be a sufficient number of comfortable offices and at least one standardizing laboratory for the testing and calibration of instruments. In addition there should be a number of small research laboratories where advanced students or members of the faculty may prosecute scientific investigations without the interference, and annoyances and disorder which result when such work must be undertaken in the main laboratory. The importance of such rooms is recognized in the design of chemical and physical laboratories, but so far scarcely at all in engineering laboratories.

Ideal Laboratory Equipment.

The equipment of engineering laboratories, while important, is comparatively of smaller importance at the start than the design and arrangement of the building, for mistakes in the purchase of equipment are less serious than the erection of a building illy adapted to laboratory purposes. Of necessity, the selection of equipment for undergraduate instruction must be along somewhat conventional lines, for certain general kinds of work are recognized as essential in the laboratory, and proper facilities for such work must be provided. While in the choice of such conventional apparatus there is an opportunity for the exercise of some individuality of judgment, it is the selection of specialized equipment that dis-

tinguishes one laboratory from another, and marks the personality of the man in charge.

All apparatus for undergraduate instruction should be of such size as to command the respectful attention of the student. A "four cat's power" engine or motor is perhaps sufficient for the instruction of the student in the motions of engine or motor testing, but such toys can hardly arouse his enthusiasm for or belief in the value of the work. In general all equipment installed should be of sufficient size to permit it to be adapted to graduate and research work, for it is only by such work that the highest ideals and the largest measure of usefulness of the engineering laboratory may be attained.

Discussion of Papers of Professors Schmidt and Richards.

Dean C. M. Woodward: Will the authors, or Dean Goss, kindly tell us how they succeed in getting the money for these fine laboratories?

Dean W. F. M. Goss: The University of Illinois is interested in questions affecting the design and efficiency of railroad equipment because Illinois is a great railroad state. This development of a locomotive laboratory by its College of Engineering is to be looked upon merely as a response to a demand which arises from many parts of the state. The College has been doing what it can to train men for the manufacturing industries, for the public service, as municipal engineers, for expert service on structural work, and in many other departments of engineering activity. Why should not the state of Illinois be equally concerned in providing itself with facilities whereby it may train men for the transportation interests and why should it not do work which will contribute to advancement of our scientific knowledge of transportation problems? These questions have been asked and they find their answer, in part, in the upbuilding of these laboratories.

President Magruder: Will Dean Goss please tell us what, in round numbers, such a locomotive laboratory and railway mechanical engineering equipment cost?

Dean Goss: The cost of a laboratory may vary within wide limits. No statement that I can make regarding a specific solution of a laboratory problem should be accepted as an index to what some one might require to solve a similar problem, under other conditions. Twenty years ago, when I began the development of plans for testing locomotives at Purdue, I had set apart for my use the sum of $8,000. This was a large sum in those days to be spent upon a single piece of apparatus. I spent half of the sum allotted for the purchase of a locomotive, and the other for installing a plant. This plant, as you all know, has been very useful. In process of time, the original plant has been materially added to and the occurrence of a fire, which destroyed the original installation, opened the way for a new start. The Purdue testing plant, as it stands today, including the building and mechanical equipment, may fairly be valued at from $20,000 to $25,000. That plant represents what was thought to be desirable twenty years ago. Meantime, locomotives have been increased in their dimensions and power. In building a plant for the University of Illinois, we were required to provide for present day needs and to allow a margin for every emergency likely to arise in the near future. The Illinois traction dynamometer is of 125,000 pounds capacity. The Illinois plant provides a wheel base of about ninety feet. The complete plant has cost about $75,000.

As you know, I am particularly interested in this field of work. This fact and a sense of justice to my colleague, Professor Schmidt, leads me to say that I, personally, am not responsible for any of the details of design which appear in this plant. It is all Professor Edw. C. Schmidt's work from beginning to end, and the credit of having brought into existence so important an installation is entirely his.

Dean Woodward: I want to suggest another idea in reference to the use of such expensive apparatus as this and to ask if any provision is made for making the results of the investigations generally accessible. In the experiment stations and farms which the government maintains many valuable results are obtained and these are made available to all who

can utilize them. I should like to know to what extent the work of such a laboratory as that described is thought to be useful to the transportation interests generally. While the primary purpose of the laboratory is to train men, that work is individual and local. While you are training the students of the University of Illinois, to what extent are some of the results useful to the entire country?

Dean Goss: I am sure that a good deal of the success that the University of Illinois has had in securing money for the maintenance of its College of Engineering has grown out of a conviction that has become common among the people of the state, that the university's function is not merely that of teaching; that it owes a duty to science, and to the commercial and manufacturing interests, and that this duty cannot well be discharged by any other agency. The citizens of Illinois are looking not merely to the work of instruction as the return received from their investment in the University of Illinois. They expect the university to do its part in helping to move the world along. Our knowledge of locomotive performance has been increased tremendously during the past twenty years, through the presence of locomotive testing plants. And I think it was not an unhappy thing that such plants should have had their origin in a college. I have felt during the past two years that an important part of the scientific work of our College of Engineering is represented by this design, which Professor Schmidt has put before you. Suppose the plant had never been built, or suppose it only served as proving the value of such a plant? The fact that a new solution of an important problem has been found is entirely worth while. While the railroads of the country generally do not have locomotive testing plants today, the number will increase. We are assured as to the value of such a plant through the tremendous activities which the Pennsylvania Railroad Company has exercised in the maintenance of its plant at Altoona, now about ten years old. So it is that in the working out of the problems of a college, it becomes quite necessary, desirable and fair, that those who are responsible for the administration

should keep continually before those who give their support, a large view of the service which is to be rendered through the development of great problems.

Of course, there are sometimes people who object and say that it is possibly all right to help the small mechanic, or to help the small manufacturer, but why should the college attempt to help the railroads, which are able to take care of themselves. Why spend state money in solving problems of the great corporations? The answer is simple. Whatever really serves the interests of a great public service corporation must, in the end, contributes to the welfare of the people who are served by the corporation. The great corporation, under right management, is merely a servant of the people. In the process of time, whatever the college may do to improve locomotive practice, will help the man who travels, or who sends his freight by train.

Dean Woodward: I am delighted to have that statement made. I expected it from the University of Illinois, the institution over which President James presides. Although he is not an engineer, he must sympathize in good work, of such broad, altruistic character. In contrast to this I remember at one time visiting, as a specially-privileged guest, a testing tank in Glasgow, Scotland. Here models of the great liners were formed and studied in every detail. But the results were all kept secret.

President Magruder: Notwithstanding the circumstances outlined by Professor Woodward the professor of naval architecture at the University of Glasgow has just been knighted by the king for his services. I trust that we may have certain of our college professors and deans knighted sometime.

THE EDUCATIONAL SIDE OF ENGINEERING DRAWING.

BY THOS. E. FRENCH,

Professor of Engineering Drawing, The Ohio State University.

I am not sure that this title is self-explanatory. It suggested itself from the wide diversity in the present methods of teaching drawing, and the rather general feeling of unrest, as indicated partially by the abnormal number of text-books on drawing, and particularly on descriptive geometry, that have been appearing recently. (A prominent publisher told me last year that he was thinking of getting up a printed form for the rejection of descriptive geometries!) The prevailing tone of defense or explanation in the introductions of these books echoes in a way the lack of satisfaction in some of the schools and a desire to do something for a change. To say that drawing is a fundamental subject in a technical school seems so trite as to be needless. It is of course recognized as a subject necessary for the student as preliminary to all his engineering work.

Drawing as a Language.

The analogy between drawing and language is often referred to. I prefer to go farther in saying that drawing, as a mode of thought expression, *is* a real and complete written language, with its orthography, its grammar and its style, its idioms and abbreviations; and that in teaching it we are not only preparing the student in a subject needed in his course but, from the very nature of it, have in our hands an exceptional cultural subject for strengthening the power and habit of exact thinking, that most difficult of all habits to fix, and for training the constructive imagination, the perceptive ability which enables one to think in three dimensions, to

visualize quickly and accurately, to build up a clear mental image. This ability, with the power of recording the visualized impression and expressing it to others, is a requirement absolutely necessary for the young designer, and its study will develop a part of his mind which has previously had practically no exercise.

As one has said, it is "the power and habit of observing accurately that marks one of the fundamental differences between the incapable man and the man of power"—and in this connection I regard memory drawing as a valuable exercise.

The Need and Value of Drawing.

As to the need of drawing, let me quote from an address of a few years ago by President Eliot.

"I have recently examined all the courses offered by the University, and I find but one (the course of theology) in which a knowledge of drawing would not be of immediate value (and even there I think it might help in some cases)."

"The power to draw is greatly needed in all the courses, and absolutely indispensible in some of them. A very large proportion of studies now train the memory, a very small proportion train the power to see straight and do straight, which is the basis of industrial skill."

As to the value of drawing, to quote again, this time from Dean Shaler:

"The value of drawing in all departments of science, not only as a language, but as a discipline of the mind, can hardly be overestimated. Many students entering Harvard University can think in one dimension, some few in two dimensions, but those who can think in three dimensions are exceedingly rare."

With this conception of the subject, that it is at once the foundation upon which all designing is based, and preëminent in its value for mental discipline and training in space intuition, engineering drawing becomes, with the possible exception of mathematics, the most important single branch of study in a technical school.

The emphasis of this discussion is directed to calling attention to the danger that the course in engineering drawing may be regarded as only for the purpose of teaching how to

draw. That some school authorities do not regard its higher value and possibilities but think that drawing means only learning to hold a T-square and make lines with a ruling pen, is indicated by the subordinate position often given to the department, in placing it in the care of inexperienced and low-salaried instructors, or often carrying it as an annex to another department.

Older Methods for Teaching Drawing.

Many of you remember the old courses in drawing, when there were fewer books and Warren was the standard. They were good old books, full of theory. The student of those days could project anything anywhere, but he could not make much of a working drawing. Afterwards Faunce's well-known book came in. The plates of this little old classic are not worn out yet, and although it has been obsolete for twenty years the book is still being sold on its record.

You will recall the amount of time spent on revolutions, and "shades and shadows," and the laborious tinting of cylinders and spheres and niches, a relic that persisted in the schools long after the necessity for it had passed. The schools, we all realize, are often somewhat behind current engineering practice. But in drawing they kept persistently behind. After blue-printing came in they continued the tinting and pricking and making fine-line tracings. You remember the transition from the first to the third angle, and the fierceness of the wars that were waged in the drafting rooms, and back and forth in the *American Machinist*. It was mainly the school-trained men vainly defending the system they had learned, against the opinions and experience of the self-made shop men. The late Professor S. W. Robinson, whose memory we all revere, was one of the earliest advocates of the third angle, but the first angle was still taught in his university, as well as in many others, for years longer than it should have been, in spite of these pioneer progressives.

In those old days there was however something of a recognized standard orthodox method of teaching drawing, en-

cumbered as it was by the French adaptations and archaic methods. In the reaction against what is seen now to have been an excessive amount of theory, and with the attempt if not to govern at least to follow commercial practice, there has been so much variance of opinion that I believe it can be said that there is at the present time a greater diversity of method in the teaching of drawing than in any other branch in a technical school.

Educational Value of Instruction in Drawing.

It is in the present-day demand for the "practical" that there lies some of the danger of losing sight of the educational value of a subject that has in it the greatest combination of possibilities for the correlation of theory and practice.

In trying to show him in the quickest possible time how to make a working drawing, and how to place dimensions and letter a title, we are *apt* to miss the opportunity of training in the student the power of space conception, and clear thinking.

His mathematics is given him for subsequent use, *and* for exercise in reasoning. This training of the perceptive ability and imagination in drawing may seem apart from pure reasoning, yet if you will agree that the foundation of right reasoning is accurate perception, it ought greatly to strengthen the power of logical demonstration.

You will recall what Young says in his "Teaching of Mathematics."

> "Mathematics makes constant demands upon the imagination, calls for picturing in space (of one, two or three dimensions) and no considerable success can be attained without a growing ability to imagine all the various possibilities of a given case."

I trust I am not misunderstood—all of this *can* be taught while he is making his working drawing if we will *do* it.

I am not advocating pure theory—as in Gauss' remark—you recall Gauss" famous toast—"I drink to pure mathematics, the only science which has never been defiled by practical application."

Present Methods of Instruction in Drawing.

Disregarding the copying courses, the giving of a series of plates to be copied by the student, which with the conception of drawing as a language to be studied and taught in the same way as any other language, does little more, as has been said elsewhere, aside from showing certain standards of execution, than copying paragraphs from a German book would do in beginning the study of the German language, disregarding these and the interminable geometrical courses, the methods now in use, with all their variations, may be divided into two general classes:

1. Those which begin with the theory of the point, line and plane, and progress to the solid.

2. Those which begin with the solid, and afterwards take up the anaylsis of lines and surfaces.

The Synthetic Method.

Considering the first division, all of the older books on drawing from Binns to Faunce began with the projection and revolution of the point, and a few of the later books still adhere to this method. The schools using this method, however, generally begin immediately with a text-book on descriptive geometry. This system was ably defended in a paper read at the Cleveland meeting of this society.

This synthetic method, as it might be called, seems logical, but experience has shown that the student has much difficulty in understanding it clearly. He starts in with a hazy idea of what it is all about, and often never comes to a clear realization of its purpose or its beauty. (We all know the not infrequent case of the good student who "flunks it dead" the first time, and gets his vision with startling suddenness on the "second trip.") In a subject which depends wholly on clearness of perception, and whose value is entirely lost if the mental picture is confused, the possibility of this condition is most unfortunate. It is this failure in comprehension on the part of the student that gives descriptive geometry its traditional bad reputation.

And when after all this elaborate theory he finds, as he believes, that it was only intended as preparation for the drawing of some simple objects, and developments, similar to those he may have made in the high school, it is little wonder that he loses his respect for it.

When we consider that many men after leaving college fail to appreciate the perceptive development and mental training that they have unconsciously received from their study of descriptive geometry, how much more is it true that the young student with his undeveloped mind, thrown head-first into this new subject, cannot realize that it has any value, cultural or practical; and accepting the principle that the highest benefit cannot be gained from any study without the interest that comes from involuntary attention, the full benefit of descriptive geometry cannot be attained from this class except in isolated cases.

The Natural Method.

While there is of course more than one route to a given destination, the second method, taking up the explanation and practice of orthographic projection by using the solid, practical mechanical drawing if you please to call it, and afterward descriptive geometry as the term is generally understood, not only has the support of abundant proof in experience, but can be defended psychologically as well. As variations, some teachers begin both subjects at once, as at Annapolis; some avoid the use of the term descriptive geometry altogether. Some have a beginning term consisting entirely of free-hand sketching. Dean Anthony has done more than any one else to show that projection drawing can be taught more easily by beginning with the solid. Without question the student gets his space intuition more clearly by handling concrete forms than by at once attempting to imagine lines and points revolving in space.

This beginning course should include both orthographic projection and the various pictorial projections, and the objects chosen should be real machine or structural parts so far as

practicable. It may go well into intersections and developments including triangulation. These problems given as drawing are worked readily and with interest. The same figures when given as special cases of descriptive geometry problems are found to be very hard.

Fig. 1.

Lettering ought to be taken up at the first of the course, freehand single stroke lettering is meant, and continued in short intensive periods through the term. But another relic, the mechanical caricatures of letters made with compass and ruling pen, should be scrapped in the same 'hell-box' that already contains the fancy titles and other typographical flourishes and curiosities of our forefathers (see Fig. 1).

Engineering Drawing.

While it is really descriptive geometry, I prefer to call all this "engineering drawing"—engineering drawing rather than "mechanical drawing." The term mechanical drawing is an unfortunate misnomer, which may mean either drawing with mathematical instruments or the drawing of mechanical things. Engineering drawing covers the whole field of technical drawing; and the important part of it *could* be taught with only a pencil and a pad of coördinate paper.

It would seem entirely beyond the scope of this topic to attempt to outline a course in drawing. It may however not be out of place to offer a few suggestions, perhaps more or less disconnected, that have to do with teaching drawing in a way to use the pedagogical opportunities.

In the first place there should be an explanation of the

purpose of the subject, calculated to arouse interest and enthusiasm (such a suggestion as this will be almost resented by the good teacher in any subject, but I have seen so many courses started with no preliminary description of aims or reasons or what was coming and why, that I am constrained to let it stand).

The good teacher will follow this later with descriptions of shop methods as they apply and of drafting room methods and organization and management.

There should be insistence on good form in the handling of the drawing instruments and on high standard of execution of the finished drawings. It is a *graphic* language and the beginner must have skill in its recording. While not the largest proportion of graduates start as draftsmen yet they must know good work from real experience with it, and while it should be explained that the execution, the making of drawings, with whatever labor and neatness and care, is not the whole purpose but, rather, incidental, the argument of the student who says "I never expect to work in a drafting room" should be met gently but firmly. He will soon find that a good drawing can be made just as quickly as a poor one.

After accuracy comes speed. Time limits carefully estimated and set, so that it is considered derogatory rather than meritorious to be putting in extra time in the drawing room. As "faith without works," so is accuracy without speed. Instead of the old extensive course in geometrical drawing there should be no geometrical figures except such as a draftsman uses. I would trace most of the plates on cloth instead of inking and require both pencil drawing and tracings. The common beginner's fallacy that careless pencilling can be corrected in inking is thus destroyed. There are many principles whose application can be worked without making finished plates, by using the "study sheet" method, working the problems in pencil only on note book sheets. Much time may be saved by giving the printed problem ready for solution. In our own case this manifolding is done on the neostyle.

VALUE OF THE RECITATION IN THE DRAWING COURSE.

The time spent on the blackboard recitation, say one hour per week, is good investment. It is in these recitations that the first exercise in writing the language and reading the language may be had. It has been our practice to begin at once in working up the visualizing ability by such methods, the instructor making the pictorial view of an object, building it up or cutting it up, the students working up the three views. They really enjoy their own introspection. This is followed by incomplete views, drawing from description, etc. Comparatively early in the course isometric and oblique, with special attention to the latter, should be taken up, first for their own sake, but more particularly for their use in translating. As soon as they are handled readily the process above is reversed and the instructor carries through the series in "orthographic" while the students interpret or translate them by sketching, in some pictorial form (see Fig. 2).

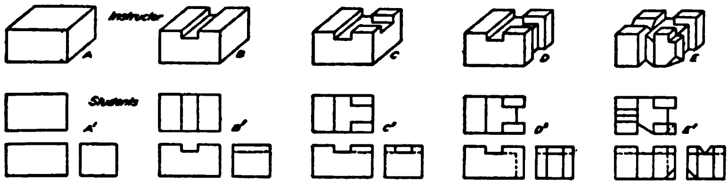


FIG. 2.

This practice has been found to be of great value. It is followed up by giving commercial blue prints from which certain parts may be assigned to be read. Details may be picked out from assembly drawings and illustrated. Difficult and puzzling shapes can by this time be deciphered; and during all these reading exercises the value of a ready ability to sketch pictorially is being unconsciously but indelibly impressed.

TRAINING IN VISUALIZING FORMS.

Getting back to orthographic projection, models may be introduced and dimensioned sketches made. I believe in the

judicious use of models. They aid in visualizing not only shape but size. The first practical experience of nearly all young draftsmen is the same. After making the half-size or quarter-size drawing of a piece they are surprised at first sight of the casting in seeing how big it is.

The student should be able to look at the drawing and see the object. He should also be able to look at the object and see the drawing, *i. e.,* to decide quickly what views would best represent it. There should be much sketching and working drawings. In these he gets the application of all the principles. He now begins to appreciate "style" in the language, not in the execution but in the composition. Some drawings have all the information but are hard to read, some are redundant and tautological, some may even have split infinitives in the dimensions!

In developments and intersections, which have been preceded by auxiliary projections and the true length of a line, the classification of surfaces can be referred to with profit, and as has already been mentioned this work may be carried on into problems such as are often given as "special cases" toward the end of the descriptive course.

With a preparation such as this, and the consequent power of reading description from lines, descriptive geometry if introduced now becomes real and fascinating. It will be appreciated for its own beauty and for its aid in solving problems whose difficulty is now recognized and whose applications are understood.

In conclusion let me contend for a better recognition of the general department of engineering drawing, including descriptive geometry. Let it be preferably a separate department, manned by a corps of efficient, experienced, well paid instructors. I believe in the rule that all drawing instructors must have had practical experience on the board, not primarily for the effect on the student, with whom the respect for practice is so marked that it often even exaggerates the real value, but principally for the instructor's view point; and it requires more than the $600 or $800 minimum to find men with the

teacher's instinct and bring them from commercial work. These are difficult subjects to teach. One of the leading mathematics men of the country has said that descriptive geometry is the hardest known mathematical subject to teach well. The reason is of course understood as being on account of the wide variation in imaginative ability among students of the same mental capacity. Some have strong powers of visualization, some are almost destitute of mental imagery (as you remember Galton found his men of science to be). I have sometimes said that it takes five years to make a descriptive-geometry teacher.

Finally, let us have drawing taught well and understandingly, for its own sake, for the sake of the subjects following, and for the students' sake, for whom, with the power it awakens, it really becomes drawing in relation to life.

Discussion.

Professor F. G. Higbee: I remember quite well the paper to which Professor French refers and also the humorous testimony which both Dean Benjamin and Dean Kent gave at the time it was read. Dean Benjamin said that he had been a practicing draftsman several years before he heard about descriptive geometry and that after he went to college he was able to find out what a hard subject it was; Dean Kent gave practically the same testimony. At that time these men felt that drawing and descriptive geometry were so closely related that they might well be taught as one subject—as drawing.

In my own teaching I have been confronted with the problem of the order in which drawing and descriptive geometry should be taught. And in order to reach a conclusion based upon more than mere opinion I have been experimenting for eight years with a number of arrangements and combinations which I hoped would settle the matter in my own mind. As a result of this just now I believe—at least as far as my own work is concerned—that it is better to give a complete course in engineering drawing first and follow it with a course in descriptive geometry. I have tried it this way and

in other ways and so far as the order affects students I can see little difference,—one way seems to work as well as the other,—but, in spite of this and of the fact that I once went on record as favoring descriptive geometry as the first course, I think there are some advantages in having the course in drawing taught before the course in descriptive geometry. Students at least get a reading knowledge of the language in which descriptive geometry is written and they learn to visualize to a certain extent.

The use of models is as important in descriptive geometry as it is in drawing. For drawing models I use parts of machines of good design, wrenches, valves, etc., and in descriptive geometry I encourage the students to build up models of their problems from their triangles, pieces of cardboard, pins, or whatever materials may be convenient. This assists them to *see* the problem as mere lines on flat paper can not. I recall an experience I had with one plodding and painstaking student whom I found working away underneath his drawing table with his T-square and triangles. I asked him what he was doing there and he replied: "Professor, I am in my third quadrant."

Draftsmen are inclined to look upon descriptive geometry as something of little use, and I think this is the result of teaching it as *geometry* rather than as drawing. Such men may know all they need to about the subject but not by that name. As an illustration of this a problem which appeared recently in a well-known technical journal is to the point. The problem consisted in finding the angle for a fitting which was to be a part of the connection between two pipes lying at different elevations. The writer of the article gave a neat demonstration of the ancient and honorable problem "To find the angle between two intersecting lines" and concluded with the astonishing assertion that "this will be found a much simpler method of solving this problem than that found in texts on descriptive geometry!"

Mr. J. S. Thompson: Will Professor French please give his opinion as whether it is desirable to have the drawing work

carried through to a considerable distance in the course which is in the hands of the drawing department, or split up and put into the hands of the separate departments?

Professor French: Drawing is a language and the different departments use that language in their own work. It may require a year and a half or, perhaps, two years in the drawing department, depending upon schedule and number of hours, to learn it but the students may at the same time be using in other departments the language they are learning. I think, however, that they should have training in the general department until they know it thoroughly in all its different expressions, and are able to use it. The "language" part of it should not be taught in the separate departments. When they apply it in special departments the students should have the language so thoroughly that all of their thoughts will be concentrated on what they are trying to express.

Professor W. H. Kirchner: I had one experience during the last two years in the line of lettering which is unique. We have at the University a school for training nurses, and it was found in the administration of the hospital that it would be a decided advantage for the young women in training for nurses to take a little work in practical engineering lettering or some slight modification of it. They decided that the bed-side sheets, the hospital reports and so on which were written in by the different nurses at different periods would present a much more uniform and acceptable appearance, if they had had training in the elements of simple single-stroke free-hand lettering. The course which these young women take is much congested, all of the morning hours being occupied with the various lectures and other duties so that I could not devote much time to them. The first year I was obliged to take them for one afternoon, two hours at a time. During each period, I found that their work showed improvement and progress for the first twenty minutes, but during the next half hour, unless they were very much rested, it deteriorated. It seems, therefore, that lettering should be done in frequent short exercises, for classes of both sexes.

SHOPWORK FOR ENGINEERING STUDENTS AT THE UNIVERSITY OF MINNESOTA.

BY J. V. MARTENIS,

Asst. Professor of Mechanical Engineering, University of Minnesota,

AND W. H. RICHARDS,

Instructor in Woodworking, University of Minnesota.

The fundamental object of shop work, as it should be administered, is to teach the student who has had little or no preliminary training in the manipulation of shop tools, the correct use of those tools, and at the same time the possibilities and limitations of the various tools which are to be found in the up-to-date shop. The student should also learn shop methods and the coöperation of various lines of shop work. We do not expect, nor do we desire to turn out expert artisans, for the average college curriculum cannot allow a sufficient time to produce such results. It is important, however, and upon that great stress should be laid, that the attainment of a fair degree of coöperation of mind and hand and the ability to lay out work should be included in the aim of instruction.

TWO IMPORTANT SECONDARY FUNCTIONS OF SHOPWORK.

The student should learn first to observe the rules enforced in the shops, especially those relative to the use of machines. It is most important that the student should learn to exercise great care in the use of all high-speed machines, not only to guard against accidents to himself but also to his associates, as machines having exposed moving parts are a menace to all and are especially dangerous to the careless ones. All machines should have protective devices installed where necessary, and a course of lectures on shop safety devices should be given early in the student's shop career.

University of Minnesota — Exhibit of Patterns.

UNIVERSITY OF MINNESOTA — EXHIBIT OF MACHINE-SHOP PRODUCTS.

The shop furnishes a splendid school of experience for the student in engineering, because it helps him to determine in a measure what his future vocation shall be. Taking the students as they present themselves, it is found that some evince especial adaptability to shop instruction. On the other hand, others seem utterly unable to acquire the ability to use shop tools with any degree of facility. In many instances a student's shop experience will indicate whether his vocation be rightly chosen or not. It is apparent that if you assume that inability to use shop tools is a fair index of a mistaken calling, when such a condition arises, it may be useful in calling attention to the error early and thus save serious loss of the student's time. In this connection, it should be urged strongly upon those who prepare the student for his course in engineering, that the preparation should be such that he may be able to read and understand simple shop drawings.

Administration of Shop Courses.

The order in which the various lines of shop work should be administered is open to question. We have considered it advisable to have the student take his carpentry and pattern work first, followed by forge, foundry and machine work. There would seem to be an argument in favor of such an arrangement inasmuch as the class of work performed in the wood shop lends itself admirably to manual dexterity and can have much to do in forming correct habits of procedure and also in instilling in the student a correct sense of proportion and of pride in the character of his work. Outside of these considerations there are certain factors entering into the arrangement of shop courses which must adapt themselves to the administration of the various lines of work.

The utility of the shop products should always be borne in mind. It is most profitable to minimize the number of strictly exercise pieces. In the wood shop the student is instructed to grasp the fundamentals of the use of wood-working tools and of wood forming. Then he is given work of a practical nature, being assigned work which may be used in construction in

some part of the shop, or patterns for pieces which are required to the further development of the equipment. We try thus to give the student the commercial sense in his shop work. The patterns are used in the foundry for the production of castings which are later machined and used in the construction of shop machines and equipment. The value of this method lies in its tendency to increase the interest of the student in the work; it also cuts down the cost of maintenance and of obtaining machines for the shops.

The time devoted to the wood work is about equally divided between carpentry and pattern work, namely seventy-two hours in each. The time is increased in the foundry to one hundred and eight hours, in which limited period each student is given some training in floor and machine molding, core making and brass casting. One lecture per week is included.

In the forge work the same principles apply. Beyond the necessary practice in welding, the pieces produced are utilized in the shops, so that there is little scrap except spoiled pieces. Bolts and other forged pieces furnish good exercises for students in the machine shop. Seventy-two hours are devoted to work in the forge shop, including one lecture per week.

Much greater time is given to the machine shop. Three hundred and sixty hours are devoted to this work for the mechanical engineering student, which includes one lecture per week for a period of a year and a half. The lectures during the last half-year relate particularly to automobile construction. The entire course in shop work for the mechanical engineering student requires a total of seven hundred and two hours. The students in electrical engineering have the same course with the exception of the last semester in the junior year, in which they have only four hours per week and no lecture, whereas the mechanicals have six hours and the lectures on automobile and gas-engine construction.

Advanced Shop Exercises.

After a sufficient preliminary training in the use of machines and tools in the machine shop, the work there tends

largely to increased efficiency. The students build lathes for the wood shop, motors for the various shops, and other equipment, and in addition construct machine and kinematic models. The work is done from their own detailed drawings. To further accentuate the commercial side of the work the students have time cards upon which they "ring in and out," using the time clock. In conjunction with the practice work, a number of shop trips are taken, and in order to train the faculties and powers of observation, detailed reports are made.

Beginning with the next collegiate year, it is proposed that these reports shall have a twofold value as each will be examined and criticized from a technical viewpoint by the shop instructors, and its language and composition will be reviewed by the Department of Rhetoric. It is expected that this arrangement will be productive of greater facility and care in the arrangement and construction of the report.

Conclusions.

Shopwork is valuable in teaching the student common engineering terms and phraseology, such knowledge rendering the following technical courses more intelligible and interesting.

It has been found that competition is a great incentive to increased interest and productiveness. It is especially true where the work is of such a character that groups may be assigned to complete equivalent tasks.

In assigning a group of students to a task it is advisable to allow the group to select its own captain, for by so doing it will exert itself to a maximum in order to produce the best results.

Discussion.

Dean C. M. Woodward: Do these students come from all over the state, from St. Paul and Minneapolis, the farming and other districts?

Mr. Richards: About sixty per cent are from outside of the "twin cities," largely from Minnesota. In some cases we do get stragglers, as you might term them, from elsewhere.

Dean Woodward: Do you give credit for the instruction in wood-work and metal-work which they have had in their preparatory schools?

Mr. Richards: We do providing it will meet with our requirements. If a boy can show he is capable of doing work which is the equivalent of our requirements we are very glad to give him full credit for it.

Dean Woodward: The reason that I ask is that in some communities, as in St. Louis, nearly all of the boys who enter engineering schools have had four years of training in shop work in the high schools, or in the manual training schools. Of course each one has constructed a project in the shop, sometimes jointly, and sometimes individually. When they come into the university where they have a shop with a totally different kind of fittings, they can enter at once upon a very much higher stage of work and deal with problems suited to college students.

Professor Martenis: Some of the students who present work for credit in our shop have rather a limited experience. The work for which they wish credit may consist of work on some particular class of machine. As our exercises comprise lathe work, planer work, milling-machine work, in fact work on all machines that we have, the credit given to a person skilled on any machine would be for work on that machine only.

Professor B. L. Newkirk: Do you not find that you very seldom give credit for any more than part of the freshman work?

Professor Martenis: Very rarely, unless the student be particularly well prepared.

President Magruder: I would like to ask Professor Woodward if a boy who has been graduated at one of the manual training high schools, such as the McKinley in St. Louis, goes to Washington University and offers his shop work at the McKinley High School for credit, how much credit is given him?

Dean Woodward: He gets no university credit because the university work is on a different plane.

President Magruder: Then as I understand, you require a certain amount of shop work equivalent to that given in the McKinley High School for admission?

Dean Woodward: Yes, the students must either have it, or they must get it.

President Magruder: If they must get it, where do they get it, if they have not had it when they apply for admission to the university?

Dean Woodward: There are a dozen places in the city, or they can do it in the university shop in extra hours.

President Magruder: Is the course so arranged that they can get four years of manual high school shop work in the university in extra hours?

Dean Woodward: No, the work that they do in the manual training school is not simply to prepare them for the shops of the university. They do any kind of work in the shops of the schools for educational work. That particular work is not required in the university at all. Every boy in the manual training high school goes through the whole course, involving drawing, art work, and work in metals, in moulding, in pattern work, in forge work, and in machine work, but they do not undertake to do any practical work. The work which they are given in the university shops, if they have not had instruction in manual training, is of an elementary nature to prepare them for the advanced work, but it does not exactly duplicate the work which they should, preferably, have had in the high school.

Professor P. F. Walker: Touching on this point of credit for school work I would say that at Kansas we give credit for work done in the Kansas City Manual Training School somewhat as has been indicated as the practice in Minnesota. There are a few other high-grade schools from which we draw, boys from which may receive a certain amount of credit also. This may amount to the whole of the freshman work in extreme cases, although we are placing our freshman work on a new basis so that we probably cannot hereafter give them credit for all of it. Such work as forging, however, can be easily learned in high schools.

We are doing something in the way of making tools, and small machines also. Our shop, in fact, is coming to have something of a commercial side to it. We have employed a mechanician, a workman of high grade, who is making the finer grades of scientific instruments, and we have a journeyman foundryman who puts in his time as an employee turning out work and at the same time does some instructional work. Thus, as our students become more proficient in the machine shop, we are in a position to put them on such work as making parts for lathes. We find that this is just as good educational work as if all their time were spent upon formal exercises. We find that we can turn out excellent work in this way and the students have a greater interest in it. We have a special ruling from the state administration which permits us to dispose of some of our product on the market.

Professor J. A. Hunter: I would like to ask if any of the new students are allowed to pass up any or all of the shop work on examination. We have coming to us men who have served apprenticeship courses in machine shops, or in woodworking and turning. We allow them to pass a limited examination in that part of the work, and then require them to devote the time gained by that to other engineering courses, perhaps in the drawing room. Is that the practice here?

Professor Martenis: Practically so. If a student is proficient in any particular line of shop work, he is given credit for that work, but he must demonstrate his knowledge of the work before he can be given credit for it. While speaking, I would call attention to another feature of our shop work, namely, the gaining by the student of a sufficient amount of shop practice to enable him to work up apparatus that he may need to use in connection with his thesis work. As students frequently carry on lines of investigation it is necessary for each to construct his own apparatus. Shop training helps him wonderfully in doing this.

Dean C. H. Crouch: Do you have journeymen mechanics working in the shops at Minnesota?

Mr. Richards: We have a mechanician to assist in the up-

keep of the equipment, but not to take part in the manufacturing work. That is entirely student work.

Professor Hunter: I was interested in the idea of having the student do all of the work here, because I have seen shops that were supposed to be school shops, in which the students got the "fag end," while the mechanics did the best part of the work. To return to the matter of advance credit, I believe that credit should be given for equivalent work wherever done.

Professor Walker: As Professor Hunter suggests, at the University of Kansas we take men from the shops on the same basis that we would take a student and give them advanced standing in almost any course for equivalent work. In case of an applicant presenting shop work for advanced credit we simply put him through some sort of examination to determine his ability before granting the shop credit.

Professor F. G. Higbee: One point in connection with this work has been touched upon which might be amplified, namely, the connection between drawing and shop work. There is a tendency for these to spread apart rather than to get together. The instructor in drawing thinks that it is the business of the shop instructor to teach the reading of drawings, while, naturally, the shop instructor believes it to be the duty of the drawing teacher to do it. At Minnesota, where do the students learn to read drawings?

Professor Martenis: In answer to this I will say that the students are assigned some certain machine to build. First they are required to get out the drawings and the details for it. The drawings are inspected and passed over to the shops where they go through one shop after another. The production of kinematic models accompanies the work in kinematics. The students turn out the drawings in devising the machine, and then the drawings are delivered to the shop men. We prefer to have the work done by the students who get out the designs, because they naturally take the most interest in the production of their own models.

Dean Woodward: I would like to ask what meaning you

attach to the word "design." You say "they design a machine," or they design something else. Does this mean merely making the drawing, or copying the drawing from some other machine, or copying the dimensions, or guessing at things, or is it really designing?

Professor Martenis: As we used it, the word "design" must not be taken too technically. The work itself is planned out as soon as the student gets a proper conception of what is to be accomplished. Of course the whole design evolves itself from the discussions between the students and instructor. The student is instructed along definite paths about the best practice to be used in connection with the devising of a particular machine and, as he gets the correct idea, he works out the details so that they will be available for shop use.

Professor Hunter: I wish to ask another question, one in regard to the supplementary reading mentioned in the paper. I have tried several different methods for conducting this reading work. One was to require certain pamphlets or books to be read at the student's own will. Another, which I am now using, is to have the readings assigned, to hold quizzes at definite intervals, and to grade on these exactly as is done in recitations. I would like to know if there is a better plan for carrying on this reading?

Professor Martenis: At Minnesota there is collateral reading demanded in connection with the shop work. That is particularly true in connection with the economic side of the work, which is not always fully covered in the recitation or lecture courses. For example, certain phases of foundry work are taken up by reading assignments in the current periodicals and possibly in a standard book on foundry practice. By such means the student is supposed to gain this knowledge outside of his regular class work.

Professor W. H. Meeker: This is one of the lines of work under my charge at the Iowa State College, where we have our courses arranged somewhat differently to fit our conditions. We start our freshmen at forge work followed by foundry work in the second term. The first term of the sophomore

year is given up to pattern making and the first half of the second term to advanced pattern making. The latter half of the second semester is occupied with steam-fitting and plumbing. The three terms following the sophomore year are given up to machine-shop work. There are two reasons for this arrangement. First, we have found that a student who has done some foundry work takes hold of pattern making with more interest and makes better progress in it. Some may wonder why we start our wood-working with pattern making. As Professor Woodward has brought out, a great many manual training schools of our state and others are now giving courses in manual training which includes bench work, carving, joinery and wood turning. When the graduates of these schools came to us we were obliged to give them credits or else start them in an advanced line of work. We had so many such cases that we finally decided to drop the bench work and turning and start with pattern making. While some of our students have not had manual training we find that we can teach the principles of joinery and wood turning along with the pattern making. In the second place, the reading of drawings for forge work is very simple, while the foundry requires no ability in reading drawings. When a student reaches his sophomore year he has had the drawing of his freshman year and is much better fitted to take hold of pattern making and to read accurately the drawings from which he must work.

I am also much interested in the giving of lectures in connection with the shop work. Professor Martenis states that a series of lectures is given with the course in machine-shop work, and I would inquire if he is also giving lectures in connection with the forge and foundry work, and other courses. It seems to me that, if pattern making is given first, it is almost necessary to have a course of lectures in order to tie it and the foundry work together. I would ask also, if Professor Martenis uses the same shop instructors to give the lectures and the shop instruction. We try to give the technical and theoretical work in the class-room, depending upon

the instructor to give only the work for which he is best fitted. We have not had very good success with the lecture system with shop classes. We find a few men who are interested but the larger part are not. We try to keep our shop sections so small that a student gets personal attention from the instructor. He thus has an individual lecture, as it were. This puts more work upon the instructor, but I believe that the results secured warrant the time and effort.

Professor Martenis: In connection with our shop work, we give a course of lectures. Each lecture deals particularly with the work which is under way at that particular time. There was a time when one instructor gave the lecture and another the shop work, but I believe that it is a better policy for the instructor who administers the shop work to give the lecture, to produce better coördination. The numbers that we have in the sections at times run quite high and it does entail extra work on the instructor to give the individual student the personal attention which he should demand, but the work seems to be given in a perfectly satisfactory manner.

Dean Woodward: Do you dignify the demonstration of a process to the class by the name of a lecture?

Professor Martenis: It may be a lecture, or it may be a recitation. We have certain text-books available so that the exercise can be given in the form of a recitation if desired.

Dean Woodward: Suppose that the instructor was going to teach a student class of thirty or forty how to make a weld. Would they arrange themselves around his anvil and near his fire and listen to him and watch him as he does the work, explaining every step. Would you call that a lecture?

Professor Martenis: No, that would properly be termed a demonstration. A lecture is given in the recitation room, where the student has only certain essential parts of the work for his immediate consideration.

Professor Kirchner: I would like to point out that these classes are arranged in the same sections for book and shop work. Some of you might get the impression that all of the sections are thrown together for a general lecture, but that is not the case.

Dean Crouch: It has always seemed to me that foundry work should come first as the student pursues his pattern work more intelligently if he has worked in the foundry and knows how each piece must be molded to get it out of the sand. Prior to last year the course was arranged in that way at the University of North Dakota. Last year it was decided to put all engineering students into one freshman class, as foundry work is not as necessary for the civil engineer as joinery and forging. My own opinion, however, is that the former arrangement is better.

Professor Flather: Responding to the remarks of Dean Crouch I would say that it does not make a particle of difference whether the pattern or the foundry work is given first. If one is given first, the students are better in the other.

Professor Kirchner: I would second Professor Flather's remarks. From an observation period of eighteen years I have concluded that it makes very little difference which one is given first.

Professor Meeker: Professor Martenis brought out the point that some men do not seem to take naturally to shop work or drawing and in some cases these men were discouraged from going on with the course, on the inference that they would not make successful engineers. I have reached the point where I am extremely cautious about drawing such a conclusion. One of the most careless men who ever went through our college shop, who was, in fact, so careless and did such crude work that the instructor shivered when he came in, realizing that a set of gears would be stripped before he went out, is now building one of the best lines of machine tools made in the country. His drawing was just as crude as his machine work. I can cite other such instances from my own experience. I do not think that a failure to take readily to shop work or to drawing is an indication that a man may not make a successful engineer. Referring to the order of the shop courses I would say that for twelve years at the Iowa State College we put the wood-working first. Since we have changed to the other order both our foundry and our pattern work have gone much more smoothly.

Professor Martenis: In reply to Professor Meeker I would say that the statement made in the paper was not an assertion. A student's inability to handle tools and to adapt himself to the various lines of shop work may be an indication of a mistaken calling. Frequently you find students who have gained the idea somewhere that nature has proposed an engineering career for them. After they have investigated the matter in a personal manner they find that they have guessed wrongly and naturally drift into other lines of work for which they are better suited.

Professor H. Wade Hibbard: During the discussion I have been listening to hear something about experimental and investigational work in the shops; the setting of problems for scientific study, analysis, test, and investigation. Are any of the college shops doing anything of that sort?

Professor E. F. Coddington: In answer to Professor Hibbard's question I will say that in the summer session at The Ohio State University this year we have one student who is doing that kind of work. While I am not familiar with the details I know that he is investigating the number of motions and the time required in setting up a jig and putting it in operation. We are, therefore, making a start.

Referring to Professor Flather's remarks I would explain that our shops are so congested that we have to give our courses in any order that we can. Hence we have arranged our shop so that we can alternate them. Sometimes we give foundry work first, sometimes the woodwork. It happens with us that the same man is at the head of both wood shop and foundry. His preference would be to give the two courses in parallel.

On the question as to whether one can determine from a student's shop work whether he has started on a wrong career or not, I will say that it is not safe to draw any conclusions from such incomplete data. Quite often our students do poorly with their theoretical and academic work, and on that account they take naturally to shop work in which they excel. Occasionally the reverse is true. The average man should do acceptable work in both shop and theory.

President Magruder: Can anyone answer Professor Hibbard's question about experimental engineering work being done upon shop tools?

Professor Walker: In the reorganization of our courses of study we have introduced, in the junior year for mechanical engineers after they have finished their actual shop practice, certain courses which consist mainly in making time studies, carrying out investigations, making studies of the methods of shop administration, preparing time cards, and work of that nature. This work is for future development so that I cannot speak from experience as yet.

Professor Adolph Shane: How many semester hours of each shop are offered by the University of Minnesota?

Professor Martenis: The hours are clock hours. To summarize these, in the wood shop there are 72 hours given to carpentry and 72 to pattern work; forge work requires 72 hours, foundry work 108, machine shop work 360 hours, and 18 hours additional are given in lectures to automobile and gas engine construction, a total of 702 hours of which 144 hours are devoted to lectures in the various branches.

President Magruder: In reply to Professor Hibbard I would say that I have not seen any engineering shop work such as he refers to done in any engineering shop in any of the forty-odd technical schools that I have visited in this country. I have seen some at the Municipal Technical School of the City of Manchester, England, under the direction of Professor Nicholson, where a thirty-inch lathe is fitted up with four or five dynamometers for measuring the pressures exerted by tools against the work. This, however, is in the laboratory and not in the shop.

At the University of Cincinnati I saw the beginning of a certain experiment about to be made a year and a half ago in the engineering laboratory, on the transmission of power and force in a shaper. The amount of force exerted by the tool of the shaper upon the work was being investigated. As Mr. C. C. Myers, of the University of Cincinnati is here, I would request him to give us some information on the subject.

Mr. C. C. Myers: We have about the same experiments being carried on at the University of Cincinnati as Professor Magruder mentioned as seeing in England. We have a Nicholson dynamometer and it is being used on experimental work both in the laboratory and in some of the coöperating shops. The shaper which Professor Magruder refers to has been used to give some interesting data, as indicator cards have been taken showing power consumption for the complete cycle. Several other tests on machine tools have been made which are interesting more from the manufacturers' standpoint.

Work similar to that described by Professor Hibbard has been carried on for some time but we find that the expense for materials in the way of castings and forgings for any series of tests proves to be a formidable proposition. We have not endeavored to duplicate Mr. F. W. Taylor's experiments in any detail. Manufacturing methods are gone into carefully, all details are analyzed and the complete problem discussed. There is not the need with our work to have actual demonstrations on machine tools in the laboratories as the students are meeting with similar demonstrations in the shops where they are working, and they are keen to recognize the weak points in any system or methods which may be proposed.

President Magruder: Professor Leutwiler, can you tell us something about what you are doing at the University of Illinois in the measuring of power of lathes and various other tools of that kind?

Professor O. A. Leutwiler: At the University of Illinois the machine shop is run on an efficiency system almost altogether. We have an efficient man at the head of it, but as a matter of fact, the students practically run the shop. The instructors are there to maintain discipline and to see that things run along smoothly. We have done some work along the line suggested by Professor Hibbard, namely, some tests on the cutting power of various types of steel. We have built one dynamometer for measuring the power required to take various-sized cuts on a lathe and this last winter one of our

seniors conducted an extended series of thesis tests on the cutting power required by various twist drills. The results were very good. Four years ago we attempted to measure the deflection of various kinds of machine tools. The apparatus was designed and built by one of our seniors in the class of 1909. The next year it was redesigned by another senior and several more tests were made. In our revision of the course we are now putting the shop work in the sophomore and junior years for mechanical engineers, and follow that work with a course along the line of shop management.

Professor Hibbard: At the University of Missouri, the shop work has been turned wholly into the manual arts. President Hill has for a long time had the belief that no man is broadly educated unless he has been educated in the use and coördination of hand, eye and mind, which is part of a liberal culture, and unless he has some appreciation of the making of things. He holds that no man is properly educated, therefore, unless he has had the manual arts. In order to overcome the prejudice of the average professor of Latin, and Greek, German, History and French for shop work, we have put manual arts into the professional school of education and have taken it out of the college of engineering. A few weeks ago the College of Arts and Sciences and of Liberal Education voted to accept for the degree of A.B. a certain number of hours taken in the manual arts. They would never have done it if we had called it shop work. The shop work, then, or more properly the manual arts have departed from the School of Engineering and gone into the School of Education. We are, in a modest way, starting a laboratory of engineering shop work. I hope next week to close a contract for a fairly large lathe driven by a high-power motor, adapted to take a forging of a ton and a half weight, to be used in learning, if possible, something in addition to what Mr. Taylor learned, after spending two hundred thousand dollars, about the breaking point of high-speed steels. To learn something also about the possible production of a lathe, to see what we can

do in the direction outlined by Mr. Myers and Professor Walker in the laboratory of engineering shopwork.

The University of Missouri School of Engineering is placed upon the professional basis with the five other professional schools, those of law, medicine, and so on. We admit no students to the engineering department direct from the high schools, but they must first take two years in the College of Arts and Sciences. We believe that most boys when they graduate from high school are just children who do not know whether they want to be engineers or doctors. We give them two years to find themselves in the atmosphere of the University. During those two years in the College of Arts and Science they get the mathematics that they need for entrance to the School of Engineering. The manual training high schools of our larger Missouri cities are splendidly equipped, some better than our own manual-arts shops. We expect to accept the work done in those better manual-training high schools, and not require any manual arts in the University. And we hope to see those manual-training high schools extend into the smaller places. We are going to have, we hope, at the beginning of our three years, the courses in manual arts. And early in those three years we shall eventually start the men in laboratory-engineering shopwork. We start this next year with some men in their third year, the last in the School of Engineering. Perhaps after a while it will be the second year, and then the first year.

Dean Woodward: I want to say how gratified I am to hear that report from Professor Hibbard. And going back to remarks of one speaker who said that his faculty did not think foundry work would be any use to a civil engineer, I would say that the foremost engineer that we had in St. Louis, the ex-president of one of the American societies, graduated from Washington University as a civil engineer. In the course of five or six years he became the most eminent mechanical engineer in the city and now he leads as an electrical engineer. He is an all-round man.

THESIS DIRECTIONS FOR STUDENTS, WITH LIST OF MECHANICAL ENGINEERING TOPICS.

BY H. WADE HIBBARD,

Professor of Mechanical Engineering, The University of Missouri, Columbia.

The degree of Mechanical Engineer is given by the University of Missouri after three years in the School of Engineering following two years in a college of arts and sciences.

The contents of this paper are placed upon the bulletin board in the mechanical engineering design room of the second-engineering-year students about the middle of the year.

This paper is divided into two parts, Directions and List of Topics. For the second-year men, both parts are important. For this society, the list is especially offered, as being the result of a very large amount of work done two years ago, comprising some 1,500 titles. It is a list of topics or suggestions more or less detailed, intended to cover the entire range of mechanical engineering, out of which thesis subjects can be formulated.

DIRECTIONS.

For the Second-Year Students. A candidate for the degree should settle upon a thesis subject at the earliest possible date, the limit being one month after the fall registration in the third (last) year of the candidate. The subject must be acceptable to the teacher or teachers under whose special oversight it comes, and to the Chairman of the Department of Mechanical Engineering, who together form the committee for that thesis.

The thesis work of a student for the first semester requires only one-fifteenth of his time in a normal full registration of fifteen credit hours per week. During this time there will be

at least semi-monthly conferences between the student and the teacher in charge of his thesis. All preparatory thinking must be done and plans fully matured, so that the actual detail work will begin promptly at the opening of the second semester. Credit and grade for one hour is given at the end of the semester upon presentation of a satisfactory written report covering the following items:

1. Selection of subject.
2. Reading upon subject selected, with authors, titles, pages read, etc.
3. Correspondence, if any, upon subject.
4. A well-planned outline of work to be done.
5. Any preliminary work which has been done.

The real work on the thesis is in the second semester. The number of credit hours permitted for registration and the same or a less number of credit hours granted at the end of the semester, with of course the grade, rest with the committee on that thesis. The minimum registration is two hours out of a normal of fifteen; the maximum is decided for each case, and depends upon the student's other required courses, upon his personality and need, the scope of the subject and the facilities for investigation.

A thesis must have

1. Title Page,
2. Table of Contents,
3. List of Illustrations (if any),
4. Syllabus,
5. Subject matter or body of the thesis,
6. Conclusion (clearly drawn and expressed in curves if possible),
7. Bibliography (if books have been consulted),
8. Index, thoroughly cross referenced.

(Then follow details as to paper, typewriting, margins, two copies, inserts, and the like.)

A thesis may be

1. A Record of Experimental Research, or
2. A Design, or

3. A Compilation (collection of the facts, arrangement of these facts, deductions from these facts).

A thesis should be an original, independent piece of work; under oversight and guidance sufficient only to prevent waste of time and to make it of most value to the student and to the profession.

A thesis should be handled by the student as a real engineer would handle it.

Out of a thesis should be obtained

1. Educational value, as
   - (a) Self-reliance.
   - (b) Thoroughness in going to the bottom of the subject.
   - (c) Spirit of research.

2. Results of value to the profession, if possible. Hope, expect and so work, that your thesis may be accepted for publication and paid for by an engineering paper.

If the thesis is to be experimental on some mechanical appliance, the appliance should be of full commercial size and the experiment made on a commercial scale, and to represent actual engineering conditions.

Care should be taken to choose a subject not too extensive to be handled properly in the time or with the money available; the thesis may well be a very small subdivision of perhaps a large subject.

A thesis is likely to be especially satisfactory if the student has been previously especially interested in the subject or has had some experience in that line.

Before choosing a subject it is wise to

1. Look at subjects of recent theses in the engineering library. Examine their contents, extent, methods, analysis, subdivisions, arrangement, etc.

2. Ask some of your outside friends, especially engineering friends, during the Easter vacation and your next summer vacation, regarding what they would like to see investigated.

3. Write and ask the same of some of the engineering firms whose catalogues you have obtained in your Student Branch of A. S. M. E.

4. Examine latest index to current periodical engineering literature.

5. Examine table of contents of A. S. M. E. annual *Transactions.*

6. Examine table of contents and also the contents of Kent's Pocket-book and Hütte.

7. Examine the analysis of papers in the A. S. M. E. *Transactions,* as given here on page 133.

8. Note the subdivisions of the entire mechanical engineering profession, as divided into five groups by a committee of the A. S. M. E., given here on page 134.

9. Note the thirty-eight sub-committees of the A. S. M. E., given here on page 135.

10. Read over the very large number of thesis topics given herewith, most of which are merely suggestive, out of which detailed thesis subjects could be formulated, and some of which are already suitable for thesis subjects as given. They are grouped in accordance with the thirty-eight sub-committees of the A. S. M. E.

11. Look at list of thesis subjects from another school of engineering, given here on page 159.

12. Read the eighty-four actual thesis subjects formulated by the Department of Electrical Engineering, on page 162.

After you have followed the above twelve suggestions, consult with one or all of the teachers of the department.

A student should expect to spend a considerable amount of his own money on his thesis equipment. As much as $50 has been so spent by a student who did not have much money and was obliged to be very economical. It has been the policy of the Department of Mechanical Engineering to buy from a student, at from one-third to one-half its cost, any apparatus desirable to be kept by the Department for further laboratory use. Equipment and instruments owned by the department, as also steam, water, gas, gasoline, compressed air, and electricity, are furnished free.

The thesis, by order of the Faculty of the School of Engineering, must be handed in on or before May 15, to the Chairman of the Department of Mechanical Engineering.

List of Topics.

1. Analysis of A. S. M. E. Papers.

1905 to 1910.

Abbreviations: A = Analytical; D = Descriptive.

"No." refers to number of papers delivered during this period.

	No.
Air Compressors, D	1
Automobiles and Materials, D	4
Aeronautics, D	1
Boilers, also Accessories, D, 8; A, 4; D and A, 1	13
Blowers, A	1
Bearings, A, 2; D, 1	3
Condensers, D	1
Cast Iron, A	1
Concrete Construction, D, 1; A, 1	2
Cement Kilns, D	1
Calorimeters, D	1
Clutches, A	1
Coke Ovens, D	1
Cleaning Apparatus, D	1
Cooling Towers, D and A	1
Conservation, D	1
Conveying and Hoisting Machinery, D	7
Dynamometers, D	3
Education, D, 2; A, 1	3
Elevators, D	2
Engines, Steam, and Engine Parts, D, 5; A, 4	9
Engines, Gas, D	2
Fuels, A, 2; D, 3	5
Foundry, D, 7; A, 1	8
Flow of Gases and Fluids, A, 2; D, 1	3
Fire Protection, D	1
Gases, Miscellaneous, D, 1; A, 1	2
Gas Power, A, 2; D, 9; D and A, 1	12
Gearing, A, 1; D, 2	3
Hydraulics, D	1
Heat & Heating, A, 1; D, 1	2
Industrial Engineering, D, 5; A, 1	6
Impact, D	1
Locomotives, D, 5; A, 1	6
Marine and Naval Eng., D	2
Meters, Gases, etc., D	6
Metric System, Argumentative.	1
Machine Tools and Mach. Tool Work, D, 3; A, 2; Argumentative	6
Metallurgical Mchy., D	1
Ordnance Work, D	1
Power Plants, D, 3; A, 2	5
Pumps, D, 3; D and A, 1; A, 1	5
Patterns, D	1
Power Transmission and Transmission Machy, D	3

Pitot Tube, D, 1; D and A, 1.	2
Photography, D	1
Refrigeration, A, 1; D, 1	2
Roof Construction, D	3
Railway Motor Car, D	1
Standards, Report of Committee	1
Smoke Prevention, D	1
Superheaters, D, 7; A, 2	9
Screws, D	2
Subway Ventilation, D	1
Salt Manufacture, D	1
Specific Heat of Steam, A, 3; D, 2	5
Turbines, Water, D	4
Turbines, Steam, D, 2; D and A, 1	3
Valves, A	1
Vapors, etc., D	1

2. Groups in Mechanical Engineering Profession.

A committee of the American Society of Mechanical Engineers has divided the scope of mechanical engineering practice into the five groups below. Some of the separate items are given under each head. The list is by no means complete, not even nearly so, neither are the items listed necessarily the most important of those which could be placed in their group. Those that are given are intended to be suggestive of the great field which is covered by the science of mechanical engineering.

1. Machinery and Apparatus for Making Machinery.

Equipment for pattern making, forging, foundry and machine shops, including all hand and machine tools and equipment for sheet metal and plate work, die sinking, stamping, annealing and all other special branches.

2. Machinery and Apparatus for the Production of Materials and Articles of Commerce and Manufacture.

Iron,	Rubber,	Cloth,
Steel,	Paper,	Shoes,
Copper,	Sugar,	Buttons,
Coke,	Alcohol,	Carpets,
Glass,	Flour,	Brick,
Paint,	Oils,	Tile,
Varnish,	Greases,	Nails,
Cement,	Thread,	Wire,
Chocolate,	Soap,	Agricultural
Starch,	Fire-arms,	Implements,
Rope and Twine,	Fire Protection,	Canned Food,
Scales, Balances,	Fire-protection Apparatus,	Stoves,
Furniture,	Ice,	Fertilizers,
Refrigerators,	Sewing Machines,	Pottery,
Dyes,	Automobiles,	Brooms,
Explosives,	R. R. Cars,	Salt.

3. Machinery and Apparatus for Executing Specified Processes.

Rolling,
Casting,
Stamping,
Tempering
Plating,
Crushing,
Grinding,
Hoisting,
Conveying,
Excavating,
Lighting,
Lubricating,
Signaling,
Fuel Gasification,
Drying,
Bleaching,
Dyeing,
Printing,
Engraving,
Painting,
Refrigeration,

Land and Water Transportation,
Adding Machines,
Calculating,
Typewriters,
Freezing,
Melting,
Pumping,
Compressing,
Pulverizing,
Evaporating,
Canning,
High Pressure Water System.

4. Machinery and Apparatus for Generating Power.

Water, Steam, Gas and Oil Power Plants and all Auxiliaries, Fittings and Connections.

5. Labor and Economy Factors in Manufacturing and Transportation Industries.

Accounting,
Industrial Betterments,
Shop, Factory and Railroad Organization,
Time Study,
Contracts,
Wage Systems,
Accident Protection,
Patents and Patent Laws,
Fire Insurance and Protection,
Specifications,
Education of Workmen and Managers,
Apprenticeship Courses,
Vocational Schools,
Technical Colleges,
Efficiency Systems.

3. Thirty-eight Sub-Committees of the A. S. M. E.

Covering Entire Range of Subdivision of Mechanical Engineering Profession.

1. Textiles
2. Paper and Wood Pulp
3. Sugar
4. Cement
5. Glass
6. Clay Products
7. Leather and Leather Products
8. Lumber and Wood Products
9. Metals and Metallurg. Mchy.
10. Foundry
11. Machine Shops
12. Agricultural Machinery and Implements.
13. Mining and Ore-Dressing Mchy.
14. Excavation and Dredging
15. Hoisting and Conveying

16. Road Transportation
17. Marine Transportation
18. Rail Transportation
19. Steam Power and Plant Equipment
20. Gas Power and Plant Equipment
21. Water Power and Plant Equipment
22. Air Machinery
23. Pumping Machinery
24. Electrical Machinery
25. Heating and Ventilation
26. Refrigeration and Ice Making
27. Ordnance and Fire Arms
28. Industrial Buildings
29. Fire Protection
30. Protection of Industr. Workers
31. Administr. Industr. Estab'mts
32. Mainten. and Deprec. Plant and Equip.
33. Relations with Architects
34. Relations with Metallurgists
35. Relations with Civil Engineers
36. Relations with Mining Eng'rs
37. Relations with Chemical Eng'rs
38. Relations with Electr. Eng'rs

4. Thesis Topics.

CLASSIFIED ACCORDING TO THE 38 SUB-COMMITTEES OF THE A. S. M. E. OF PREVIOUS PAGE.

1. TEXTILES.
2. PAPER AND WOOD PULP.
3. SUGAR.
4. CEMENT.
    1. (See 19 for concrete boiler settings, concrete stacks, concrete expansion and contraction).
    2. Conveyors in cement plant (see also 15).
    3. Concrete-block machinery.
    4. Machinery for manufacture of Portland cement.
    5. Foundation bolts in engine concrete foundations.
    6. Dampness penetration of concretes, experimental.
    7. Abrasion of concrete.
    8. Electrolysis of reinforcement.
    9. Tests of Portland cements, slags, etc.
    10. Tests of stones and sands suitable for concrete.
    11. Tests of raw materials for Portland cement.
    12. Geological and commercial (as regards fuel, transportation, labor supply, demand) map of Missouri materials suitable for manufacturing Portland cement. Involves considerable knowledge of chemistry.
5. GLASS.
    1. (See 29 for wire-glass in fires).
    2. Tests of the various prism glasses for deflecting light into rooms.
    3. Heat transmission of different thickness of same glass.
    4. Heat transmission of different thickness of different glasses.
    5. Heat transmission of different thickness of different glasses, with air space between.

6. Investigate possibility of making air compressor or in general a gas compressor of this material possibly reinforced.
7. Investigate possibility and limitations of its use for bearings, coefficient of friction.
8. Relative strength of wire-glass *vs.* plain plate glass.

6. CLAY PRODUCTS.
   1. Resistance to flow *vs.* diameter, of tile flues and brick flues.
   2. Expansion and contraction of fire-brick.
   3. Fire-brick; refractory *vs.* tough. Cooperation with chemical engineers.
   4. Fire tile for boiler tubes.
   5. "Compilation Thesis" of clay-product manufactures of Missouri.
   6. Iron-reinforced fire-brick.
   7. Brick-making at Miller's plant, Columbia; analysis of mechanical engineering and scientific manufacturing.

7. LEATHER AND LEATHER PRODUCTS.
   (Leather Belts, see 11).
   (Belt conveyors for coal, etc., see 15).
   Shoe-making machinery.

8. LUMBER AND WOOD PRODUCTS.
   1. Engineering uses of wood; freight cars, pattern shops, aeroplane frames, aerial propellers. (Propeller design, see 20: 73).
   2. Development of "The Art of Cutting Wood."
   3. Tests of tools and cutting edges, speeds, etc., for wood-working machinery.
   4. Paint for wood preservation. Coöperate with chemist.
   5. Tests of wood.
   6. Specifications for the purchase of wood.
   7. Characteristics of wood.
   8. Furniture-making machinery.
   9. Wood-working machinery.
   10. Timber-preserving plants.
   11. Causes of wood deterioration. (Care of patterns, see 10).
   12. Heat transmission of woods; dry and wet.
   13. Machinery for lumbering.

9. METALS AND METALLURGICAL MACHINERY.
   1. (See 11 for tool steels, "Art of Cutting Metals," springs).
   2. (See 10 on foundry).
   3. (See 19 for metal deterioration by superheated steam).
   4. Specifications for purchase of metals.
   5. Tests of metals in civil engineering materials laboratory.
   6. Repeated loads. Compound loads. Elastic breakdown.
   7. Effects of percentages of vanadium, tungsten, nickel, etc. in steels.

8. Protective coatings for metals (paint, magnetic oxide, concrete).
9. Tests of above.
10. (On paint for wood, see 8).
11. Geological map of materials suitable for good paint.
12. Hardness tests of metals by scleroscope.
13. Friction tests of materials.
14. Forging presses; design.
15. Blast-furnace machinery.
16. Rolling mills.
17. Open-hearth furnace machinery.
18. Electric welding, tests of welds.
19. Oxy-acetylene welding and cutting.
20. Gas producers for metal heating. (See 20 for gas producers in general).
21. Hydrostatic tests of cast steel cylinders.
22. Hydrodynamic shock tests of cast iron cylinders.
23. Hydrodynamic shock tests of cast steel cylinders bushed with cast iron.
24. Deterioration of wrought iron in repeated working.
25. Growth of cast iron in repeated heatings.
26. Case hardening by carbon monoxide.
27. Heat treatment of spring steel. (See 11 on springs).
28. Corrosion tests of metals. (See 21, 25 and 26 for pipe corrosion).
29. Drop forging.
30. Plate pressing; hot, cold.
31. Production machinery in blacksmith shops.
32. Electric steel manufacture.
33. Etching; microscope; microphotograph; in the study of metals, heat treatments, etc.
34. Microstructure in fatigue of metals.
35. Heat treatment of alloy steels.

10. Foundry.
1. (See 15 for bucket materials, in hoisting and conveying machinery).
2. (See 8 on wood for patterns).
3. (See 9 on metals).
4. Core making; core mixtures, temperature of baking.
5. Baked sectional molds in machined, metal flasks.
6. Use of cores in the place of patterns in steel foundry. (See Commonwealth Steel Co. of E. St. Louis, and Federal Steel Co.).
7. Location of deposits of molding sand in Missouri.
8. Molding sands; composition for different purposes, special sand for facing molds for steel castings.

9. Pattern design for steel castings.
10. Shrinkage of steel castings.
11. Strength of steel castings.
12. Cause and prevention of blow-holes in steel castings.
13. The field for very high strength cast "gun iron."
14. Recent developments in malleable cast iron.
15. Classification of patterns.
16. Care of patterns.
17. Use of chills to prevent shrinkage cracks in difficult castings.
18. The continuous foundry. (Compilation thesis).
19. Air hoists for foundry. (See also 15 for hoists and conveyors).
20. Machine molding.
21. Pneumatic rammer.
22. Jarring machines for very large work.
23. An exclusive molding-machine foundry.
24. The lifting pressure of molten metal on cores.
25. Experimental study in Univ. of Missouri foundry on the shrinkage problem in iron castings of various shapes.
26. Various mixtures of pig and scrap.
27. Fuel used per ton of iron.
28. Temperature of different zones.
29. Air requirements; power to drive blower.
30. Fluidity of various mixtures.
31. Utilization of waste heat in foundries.

11. Machine Shops.

1. (See 31 on shop costs of production and other administrative problems). (See 28 on location of machines).
2. Analysis of the manufacture of parts of a small straightening press.
3. Location of motors on machine tools. (See 24 on electrical machinery).
4. Limitations in individual motor drives for small machines.
5. Springs; (see 9 for heat treatment of spring steel); analysis of stresses, design, tests, materials.
6. Friction as an aid to springs; spring dampening; shock absorbers; the work of recoil.
7. Limit of pressure for ball bearings.
8. Tests of roller bearings.
9. Experimental study of thrust bearing.
10. Shaft hanger design.
11. Analysis and field for shafting as transmission machinery.
12. Clutches; holding power, ease of release, durability.
13. Belt shifters, durability.
14. Belting upkeep.

15. Belt deterioration.
16. Leather belts.
17. Belt fastenings. (See 32 on Maintenance and Depreciation).
18. Horsepower of belting.
19. Rope drives for industrial plant.
20. Tests of ropes for rope drives.
21. Sheaves for rope drives, diameter, slot, material.
22. Chain-belts for machines:—friction, strength, deterioration (strength, slackness, efficiency).
23. Uses of power transmission dynamometer, tests with same.
24. Efficiency tests of some of form of universal joints carrying different loads.
25. Efficiences of various cut gears, analytically and experimentally determined.
26. Efficiencies of worm gears of different angles.
27. Lubricants: (Flash, chill, density, viscosity, friction, carbonization tests—all as related to costs).
28. Viscosimetry of remixed grease.
29. Viscosimetry of grease under great pressure.
30. Tests of hard grease as lubricant.
31. Amount and type of lubricant for various metals.
32. Pressure and lubrication.
33. Anti-friction metals. (See 19 for engine lubrication).
34. Grinding machinery; methods, preparation of work, field, costs, experiments.
35. Magnetic clutch for grinding machinery.
36. Magnetic clutch for metal cutting machinery.
37. Tests of tool steels.
38. Tool holders.
39. Several tests out of Taylor's "Art of Cutting Metals."
40. Drills; drill jigs.
41. The cold chisel as standardized for the pneumatic hammer. (See 22 for air machinery).
42. The scientific selection of files.
43. Experimental study of a file for cast iron (adapting a power hack-saw machine).
44. Analysis of a vertical-spindle, high-powered milling machine.
45. Die and stamp presses for cutting or shaping thin cold metals.
46. Fly-wheel presses.
47. Mechanical engineering analysis of several makes of typewriters, as regards manufacturing and operation.
48. Household sewing-machine efficiency tests.
49 Kinematics of sewing-machines.
50. Wedges.

12. AGRICULTURAL MACHINERY AND IMPLEMENTS.
1. Cooperation with an agricultural student in a thesis.
2. Tests of farm gasoline engine.
3. Farm gasoline engine troubles.
4. Farm tractors.
5. Stresses in mowing machine parts. Ditto other machines.
6. Windmills.
7. Tests of lawnmowers. (See 20 for power lawnmowers).

13. MINING AND ORE-DRESSING MACHINERY.
1. Coal-mining machinery, Missouri *vs.* Illinois mines.
2. Mining progress in Missouri.
3. Hoisting engines. Cables.
4. Mine cars.
5. Underground haulage plants; steam, cable, electric.
6. Drills.
7. Mining machines.
8. Ventilating fans.
9. Drainage.
10. Tipples and towers.
11. Screens.
12. Make complete design, specifications and estimates for mine near Columbia.

14. EXCAVATING AND DREDGING.
1. Sewer trenches.
2. Dredger.
3. Use of hydraulic nozzle in excavating, as over quarry in St. Louis Cement Co.
4. Centrifugal pump in dredging.
5. Pump *vs.* shovel.
6. Design of an electrically-driven shovel (in place of a steam shovel).

15. HOISTING AND CONVEYING.
(See 10 for air hoists in foundry).
(See 13 for mine hoists).
(See 19 for coal crushers and pulverizers).
(See 4 for conveyors in cement plant).
1. A. S. M. E., Vol. 30, p. 123–275.
2. Belt conveyors for coal, ashes, ore, etc.
3. Tests of belt material for above.
4. Waterproof tests of belt material.
5. Abrasion; resisting qualities of belt material.
6. Belt-pulley diameter as related to life of belt.
7. Angles of repose of various materials under various conditions.
8. Belt-roller supports.

9. Fillers and dumpers.
10. Fundamental principles of endless conveyors, and discussion of all such conveyors by those principles.
11. Relative importance of requirements for conveyors in locomotive coaling station.
12. Bucket conveyors, friction, bucket material, lubrication, reciprocating feeders.
13. Scraper conveyors.
14. Reciprocating trough conveyors.
15. Screw conveyors.
16. Finger or hook conveyors.
17. Endless apron.
18. Aerial cable ways.
19. Pneumatic and water conveyors.
20. Chutes; angles of flow; roller chutes.
21. Freight-house conveyors.
22. Department-store cash and bundle conveyors.
23. Railroad and steamship power ramps.
24. Brewery conveyors.
25. Ice conveyors.
26. Cranes; traveling, trolley.
27. Sheave diameter as related to life of wire rope; or to physical qualities or chemical composition of the steel.
28. Wire rope tests (Kent).
29. Chain tests.
30. Hook design; tests.
31. Locomotive cranes; railroad wreckers.
32. The steam power plant of a locomotive crane.
33. Clam-shell buckets for run-of-mine in cars.
34. Industrial railway; cable, steam, electric, compressed air power.
35. Mechanical equipment of ore and coal docks of Great Lakes ports, for loading and unloading.
36. Coal-car dumping machines.
37. Crane installations and methods with English tarpaulin-covered flat cars.

16. Road Transportation.

(See 20 for automobiles).

1. Stone crushers. (See also 4).
2. Road rollers.
3. Road scrapers.
4. Wheels.
5. Tires.

17. Marine Transportation.

1. Marine water-tube boilers, as especially adapted for use on the Great Lakes.

2. Producer gas for marine work.
3. Marine steam turbine, compilation of results.
4. Small gasoline power plant for launch.
5. Power equipment for submarines.
6. Hydroplane. (See 20 for aeroplane propellers).

18. Rail Transportation.

(See 13 for mine cars and haulage).
(See 15 for industrial railway).
(See 20 for Diesel locomotive).

1. Design of a locomotive boiler.
2. The support of the crown sheet of the locomotive fire box.
3. Stresses in boiler produced by temperature changes.
4. Experiments on heat transfer with a boiler tube, varying the length, diameter, gas velocity and temperature, water velocity, etc.
5. A study of the locations of broken stay bolts, with causes and remedy.
6. Life of stay bolts; tests by alternate bending, while hot and stretched, of different lengths, designs and materials.
7. The locations of cracks in locomotive boilers, causes and remedies. (Moberly shops.)
8. A study of locomotive boiler explosions.
9. The ignorant or vicious methods of workmanship in boiler shops.
10. The periodic inspection of locomotive boilers.
11. Comparison of mechanical stokers for locomotives.
12. Experiments on exhaust nozzles and smoke stacks, with steam, without gas; first connecting up with tests for American Railway Master Mechanics Association.
13. Mechanical draft for locomotives (Forney).
14. Smoke diminution.
15. Experiments on the causes of variation in efficiency of steam jet as a gas ejector (glass ejector tube and visible smoke).
16. A comparison of superheater designs for locomotives. (See also 19 for superheat.)
17. The superheating effect of steam pipes in smoke box.
18. Theoretical determination of correct amount of superheat for a given locomotive.
19. Thermodynamic analysis of Mallet articulated compound locomotive using superheated steam.
20. The B. t. u. loss in air-pump exhaust.
21. The increase in efficiency by using a feed pump and heating feed water by exhaust steam from feed pump or air pump.
22. Comparison of theoretical valve motion diagrams and their adaptability for use in designing or analyzing locomotive valve gears.

23. Study of various locomotive valve gears.
24. The balancing of slide valves.
25. Power reverse gears.
26. B. t. u. wall loss from live steam to exhaust-steam passages in saddle casting.
27. Hydrostatic tests of full-sized pistons of different designs, cast iron and cast steel.
28. Piston packings for cylinder or piston valve.
29. Sight-feed lubricator with saturated and superheated steam.
30. Pump feed lubricator.
31. Piston-rod packings.
32. Cross-head designs.
33. Stresses in locomotive connecting and parallel rods.
34. Mathematical or experimental analysis of loads on one of the details of a connecting rod.
35. Journal boxes for driving axles; design; materials (cast steel, cast iron, gun iron, phosphor bronze, combinations); lubrication, bearing pressures.
36. American and European car axle boxes.
37. Stresses in car axles.
38. Locomotive trailer truck designs.
39. Design of front power truck of Mallet articulated compound locomotive.
40. Compression, inertia and counterbalancing in locomotives.
41. Balanced locomotive.
42. Vertical and horizontal rail stresses induced by steam and electric locomotives.
43. Tests of rail joints.
44. Analysis of mechanical efficiencies of locomotives of different designs and under different conditions.
45. Curves of "characteristics" of a locomotive.
46. Rational design of cast steel locomotive frame.
47. Rational design of one-piece cast steel tender frame.
48. Structural steel tender frame.
49. Mechanics of engineering analysis of a steel coal car; steel passenger car.
50. Mechanics of engineering analysis of a six wheeled passenger car truck.
51. Hopper-bottom mechanism for coal and ore cars.
52. Theoretical and practical analysis and comparison of several varieties of car couplers. (On draft gear see 11 for springs, shock absorbers.)
53. Analysis of the elements in stopping a train.
54. Foundation brake design.
55. Truck brake design.

56. Development of engineman's brake valve, triple valve, slack adjuster, brake beam, hose coupler, automatic air couplers.
57. Analysis or tests of preceding.
58. Tests of hose.
59. Tests of air pumps. (See 22 for other compressed air).
60. Train lighting and ventilation.
61. Toilet equipment in cars.
62. A locomotive test, if accompanied by draw-bar pull and track profile, etc.; suitable instruments and connections; safety.
63. Study of train resistance.
64. Locomotive terminals. (See 15 for power handling of coal and ashes).
65. Smoke diminution at locomotive terminals.
66. Coaling station equipment.
67. A complete coal-premium system for locomotives.
68. Lay-out of locomotive or car repair shop.
69. Design, construction, operation and repair of locomotives and cars; (taking a detail).
70. Specialized machinery for construction or repair of locomotives and cars.
71. Depreciation of railway equipment. (See 15 on power handling for freight terminals).
72. Signal and interlocking machinery.
73. Compilation of correspondence with the industrial agents of railroads interested in upbuilding manufactures in Missouri.

19. Steam Power and Plant Equipment.

(See 6 on fire brick and tile).
(See 25 for heat distribution from central heating plant in a city).
(See 17 for marine water tube boilers, especially on Great Lakes).
(See 15 for coal and ash-handling machinery, belt conveyors, etc).
(See 11, machine shop, on belting, rope drives). (See 13 for mine hoisting engines).
(See 25 for concentration, evaporation and drying in the industries).
(For Central Station Economics see also 24).
(See 18 for additional topics).

1. Coal tests of Missouri coals.
2. Inexpensive and quick (but fairly accurate) methods for learning the real commercial value of coals for the small user who wishes to select his coal.
3. Coal specifications.
4. Coal deterioration.

5. Coal *vs.* coke (gas house or coke-oven coke) for house use.
6. Tests of heaters for heating water in residence; (1) coal, (2) gas.
7. Tests of laundry stoves without water back, for heating wash boilers and flat irons.
8. London down-draft kitchen range for smoky coal.
9. Flue gas analysis.
10. Influence of hydrogen, CO and moisture on chimney losses.
11. CO_2 recorders.
12. Comparison of pyrometers.
13. Comparison of coal calorimeters.
14. A study of boiler explosions.
15. The inspection and insurance of stationary boilers; lessons of the statistics.
16. Application of the two general principles in boiler design: (*a*) changes in steam pressure must not alter the shapes of the boiler; (*b*) changes of temperature in the metal will surely cause alteration in shape, and must be provided for safely or the temperature changes avoided.
17. The selection of steam boilers.
18. Problems of radiation.
19. Interrelations of conduction, convection and radiation in boilers.
20. General conditions for boiler economy.
21. Compilation thesis of tests made by *disinterested* people, not by manufacturers, sellers or agents, to show what may reasonably be expected of boilers, engines, turbines, etc.
22. Effect of rate of driving upon over-all boiler efficiency.
23. Economy of heating air supply; experiments in laboratory.
24. Increase of coefficient of heat transfer from hot gases to water in boilers from 3 to 1000. (See *Power*, November 21, 1911, p. 767. See Lucke in *Transactions* of Am. Ry. Master Mechanics Assoc., 1909). (See 25 for heat transmission in heating and ventilation).
25. Thin scale blisters.
26. Gas and water-scrubbing principle in boilers; compilation, tests.
27. Counter current.
28. Steam flow meter.
29. Relations between intermittent feed, boiler pressure, draft and furnace conditions, and reading of steam flow meter. (See Hunter curves, St. Louis).
30. Boiler settings of reinforced concrete; plate-covered settings.
31. Expansion and contraction of reenforced concrete.
32. Fire-resisting tests of concrete made of cement and crushed fire-brick.

33. Special boiler furnace settings; length of fire-brick arch.
34. Tests of boiler steel worked at objectionable blue temperature; ductility, strength, cracking.
35. Tests of boiler steel at blue temperature (same for cast iron).
36. Durability test of clay tile for boiler tubes.
37. The most economic riveted boiler seams, considering every factor and including interest, etc.
38. Boiler proportions for blast furnace gas.
39. Smoke recorders.
40. Study of smoke, by Ringelmann charts, and by smoke gage, of our Columbia factory and business and residence chimneys, with causes and improvements.
41. Relation of character of coal to prevention of smoke.
42. Comparison of mechanical stokers.
43. The favorable features of mechanical stoking.
44. Necessary features for the securing of successful operation of mechanical stoking; speed, coal gate and damper opening.
45. Deterioration of metals, especially of cast iron in superheaters.
46. Specific heats of superheated steam and gases.
47. Coal crushers; jaw, rotary, flail.
48. Coal pulverizers. (See 15 for coal and ash-handling machinery, belt conveyors, etc.).
49. Reinforced concrete stacks; lining.
50. Effect of smoke gases on concrete setting of chimneys.
51. Corrosion of concrete and of reinforcement, by sulphur.
52. Mechanical draft.
53. Comparison of prime movers; steam (reciprocating engine, turbine), gas, water.
54. Engine tests using wet steam, dry saturated steam, and superheated steam; entropy diagram analysis.
55. Turbine tests of same kind.
56. Power plant of office building.
57. Friction of steam on rotating discs.
58. Heat storage; heat flywheel; Rateau regenerator; experiments on small scale in laboratory.
59. Experiments with steam-turbine nozzles.
60. Tests of steam turbine running against various pressures of exhaust steam heating.
61. Experiments on dry-tube condensing for surface condensers.
62. Influence of tube shape in surface condensers.
63. Tests on the problems of the cooling tower, spray and pond.
64. Design of most efficient fan for cooling tower. (See also 25).
65. Moisture in exhaust steam; tests to determine moisture in steam and the gain in capacity of condenser if the moisture were removed by means of a separator.

66. Heat transfer to water at temperature below 212°, (possible large variety of conditions).
67. Heat transfer in economizers.
68. Incrustation, corrosion, priming and remedies.
69. Water softening, machinery for, effect of scale.
70. Steam-pump tests; conditions of engine tests above.
71. Injector tests under various steam and water conditions.
72. Tests of sight-feed lubricator, cast iron with superheated steam, and lubrication.
73. Feed-water regulators.
74. Precise water-level control by use of steam separator or steam loop or otherwise.
75. Cracking off thin scale in vertical water-tube boiler by contraction and expansion of corrugated tubes by intermittent feed regulation.
76. Steam separators.
77. Steam-pipe design; piping systems.
78. The flow of high-pressure steam in pipes of various sizes, also through bends and valves.
79. Bending pipes at brittle blue heat.
80. Investigation of quality of steam to Sturtevant engine as affected by taking steam from bottom or top of steam main.
81. Experiments with graphite and with oil-graphite lubrication of steam cylinders and valves. (See 11 and 18 on lubricants).
82. Oil separators.
83. Cost of power; losses of power in factories.
84. Power-plant load-factor betterment by (1) heating the building or shop; (2) heat distribution by sale; (3) combining electricity production with ice making or with pumping.
85. Indicator reducing motions in University of Missouri laboratory.
86. Tension of indicator-drum springs.
87. Stretch and durability tests of indicator cords.
88. Suitable sizes for indicator diagrams; steam, air and gas, height and length.
89. Producing an entropy-temperature diagram direct by instrument.
90. Comparison of steam calorimeters.

20. Gas Power and Plant Equipment.

1. Gas works economies.
2. Gas meters; mechanical, thermo-electric.
3. High-pressure gas transmission (as to farmers many miles away from Camden, N. J.).
4. Gas velocity and Pitot tube.
5. Gas analysis.
6. Gas calorimetry.

7. Cleaning of gas.
8. Isolated gas, gasoline or acetylene plant for lighting a farm house and barns.
9. Compression and storage of Pintsch gas.
10. Transportation of stored acetylene gas.
11. By-product gases and fluids.
12. Cleaning of blast furnace gas for use in steam boilers and in gas engines.
13. (See 9 for gas producers in metal heating).
14. Design thesis or compilation thesis on bituminous gas producers.
15. Experiments in the physical theory of coal carbonization.
16. Clinkering and caking in gas producers.
17. Causes in bituminous producer for variations between theoretical estimates and subsequent analysis.
18. Decomposition of tar.
19. Internal combustion fuels.
20. Gasoline fortified with ether, picric acid or other high explosive.
21. Alcohol in internal combustion engines.
22. Explosion of carbon dust; early lycopodium engine.
23. Carbon dust as an engine fuel.
24. Explosion of gases in a closed vessel.
25. The effect of different pre-explosion pressures upon explosive mixtures.
26. Stratification of charge in two-cycle engines.
27. Fluctuations of explosion pressures under constant load conditions.
28. Explosion waves,
29. Burned gases in dilute mixtures, and combustion rapidity.
30. Suppression of heat at combustion.
31. Specific heat of gases at high temperatures.
32. Carbon deposits and rich charges, for various fuels.
33. Cooling of air and gas supply as a power gain for overloads.
34. Heating of air and gas supply as an efficiency gain for underloads.
35. Tests of carbureters for gasoline, alcohol, fortified liquids, etc.
36. Experiments on size and length of small passages as a backfire check.
37. Automobile ignition.
38. Experiments with jump spark.
39. Normal *vs.* heavy spark.
40. The automobile magneto.
41. Cam design for very high-speed engines.
42. Waste heat of gas engines.
43. Economical use of compressed air for starting gas engines.
44. Diagnosis and remedies for starting and running troubles, the engines being divided into classes.

45. Experimental production of above troubles.
46. Automobile engine lubrication.
47. Experiments on carbonization of cylinder oils.
48. The lightening of reciprocating parts of automobile engines.
49. Special steels in automobile construction. (See 9 on alloy steels and heat treatments).
50. Radiator efficiency,
51. Air-cooled motors.
52. Experiments on shapes of ribbing for air cooling.
53. Comparison of brake efficiencies with the different cycles.
54. Practical conditions limiting ideal efficiency.
55. Analysis of difficulties delaying the gas turbine.
56. The compound gas engine.
57. Diesel engine, and locomotive.
58. Recent developments in large gas engines.
59. Small gas engines.
60. Experiments with a small gas engine.
61. Experiments on a two-cylinder gas engine using oil and the Diesel cycle.
62. On automobiles, except for engine, see 16.
63. The dust problem in vehicle machinery.
64. Tests of motor-cycle engine.
65. (See 12 for farm tractors and farm gasoline engines).
66. Power lawnmowers. (See 12 for lawnmowers).
67. Aeroplane materials; wood, metal, cloth.
68. Factors of safety in the parts of an aeroplane.
69. Wind pressure on aeroplane surfaces, struts, engine fronts, aviator, etc.
70. Automatic stabilization by center of pressure, by mechanical device.
71. Tests of efficiency of aeroplane propellers.
72. Use of anemometers and smoke.
73. Propeller design.
74. Propeller rupture.
75. The motion of free and constrained solids through air.
76. Balance sheet of energy used and wasted.
77. Air *vs.* water radiation.
78. Tests of aeroplane engine.
79. Centrifugal analysis of Gnome engine.
80. Gyroscopic analysis of Gnome engine.
81. Proportions of exhaust manifold.
82. The law of trespass in aeronautics.
83. Transportation common-law evolution and its return influence upon the engineering of transportation.
84. (See 17 for hydroplane).

21. Water Power and Plant Equipment.
   1. Turbine tests.
   2. Impulse wheels.
   3. Analysis of very small hydro-electric plants.
   4. Hydraulic machinery (presses, riveters, etc.).
   5. The design of joints for high-pressure street mains.
   6. Tests of flange couplings under repeated stresses.
   7. Reducing valves.
   8. Experiments on the stresses induced in pipe lines by the sudden closing of valves.
   9. Shock.
   10. The bursting of pipe fittings.
   11. Corrosion of high-pressure wrought iron street mains. (See 25 for pipe corrosion).
   12. Flow of water in one-inch pipes; curves, angles, straight.
   13. Flow of hot water in one-inch pipes; curves, angles, straight.
   14. Effect of changes in diameter upon flow of cold and hot water. (See also 25).
   15. Discharge from pipes through branches and side orifices.
   16. Comparison of water meters.
   17. Large water meter; mechanical type, venturi type, elbow type.
   18. Pitót tubes and pipe angle, as a water meter.
   19. Pitot-tube experiments.
   20. Weir experiments.
   21. Orifice experiments.
   22. Nozzle experiments.
   23. Fire nozzles.
   24. (For automatic fire sprinkler, see 29).
   25. The motion of a solid through a liquid.
   26. Impinging jets.
   27. Friction in hose.
   28. Lawn sprinklers.

22. Air Machinery.
   1. Vacuum house-cleaning; tests of machines, nozzles, hose, dust catchers.
   2. Tests of air-using tools (portable and semi-portable).
   3. Re-heating of compressed air just before using in air machinery.
   4. Tests of different methods of reheating.
   5. Piston compressors *vs.* turbo-compressors.
   6. Design of a piston compressor.
   7. Design of a turbo-compressor.
   8. High-pressure centrifugal compressors.
   9. Pre-coolers, inter-coolers, after-coolers.
   10. Cold *vs.* engine-room supply of air to our laboratory air compressors; same for the Diesel engine.

11. Transmission of compressed air.
12. Experiments on the performance of a windmill.
13. Experiments with sand blast.
14. Placing paint and cement by the air nozzle.
15. (See 11 for pneumatic cold chisel).
16. (See 18 for air brake).

23. Pumping Machinery.
1. (See 13 for mine drainage).
2. Deep-well pumping.
3. Tests of different types of deep-well pumps: piston, turbine air-lift pumps.
4. Air lift.
5. Different arrangements of air-lift pumps.
6. High-pressure centrifugal pumps.
7. Steam drive *vs.* electrically-driven piston or turbine, pumps.
8. Tests of oil-engine or steam-engine-driven centrifugal pump for irrigation, where water is close to surface (e. g., Garden City, Kansas).
9. Tests on pumping engines with reference to cylinder condensation.
10. Tests of laboratory steam pumps.
11. High efficiency.
12. Water-works economies.
13. Analysis of the non-break-down sump pump of the Penna. R. R. Terminal, New York, as designed by Westinghouse, Church, Kerr & Co.

24. Electrical Machinery.
1. Steam and gas central-station economies.
2. Effect of power factor in economy of plant.
3. Use of floating synchronous motors to improve power factor.
4. Electrical machinery analysis as relating to mechanical engineering uses.
5. Use of induction motors.
6. Analysis of the mechanical engineering features of electrical machinery.
7. The most common troubles in electrical machinery; their diagnosis and cure.
8. (See 11 for location of motors on machine tools).
9. Design of an electrical-driven shovel, in place of steam shovel (see 14).

25. Heating and Ventilation.
1. (See 13 for mine ventilation).
2. (See 18 for train heating, ventilation).
3. Warming of air; divide into details.

4. Temperature and humidity control in heating.
5. Humidifying plant.
6. Cleaning of air.
7. Tests on air filters.
8. Efficiency tests of house furnaces.
9. Gas leakage in hot-air house furnaces.
10. The under-stoker house furnace.
11. High-temperature water heating.
12. Rapid-circulation hot-water heating; analysis, tests.
13. Accelerated radiation.
14. Heating by steam pipes buried in concrete flooring. (Morse Chain Co., Ithaca, N. Y.).
15. Transmission of heat through house walls, etc.
16. Moving of hot, warmed and unwarmed air by a fan.
17. Air-pipe diameter, bends, cross-section shape.
18. Tests of shapes of fan blades, speeds, etc.
19. Fan tests; capacity, pressure, power required. (See also 19).
20. (For cooling tower fan see 19).
21. (See 20: 73 for aeroplane propellers).
22. Electric fans.
23. Tests of anemometers.
24. Flow of cold water, hot water and steam in one-inch pipes. (See also 21).
25. Flow of the above in curves, angles and straights.
26. Effect of diameter changes on each of above two.
27. The influence of pitch on the flow of water (and steam and air) in pipes.
28. Heat distribution from central heating plant in a city.
29. Use of high-pressure, high-velocity distributing mains for steam heat, as against the opposite.
30. Pipe corrosion. (See 9 for corrosion of metals, 21 of water pipes).
31. Tests during service in church of Columbia.
32. The ventilation of the agricultural college auditorium.
33. Tests of baking ovens heated by city gas.
34. Tests of laundry drying-plant.
35. Centrifugal drying.
36. Concentration and evaporation in the industries.
37. Tests of heat loss by buried steam and hot-water pipes; naked, wood stave, conduit, tunnel.
38. Deterioration of combustible laggings.

26. Refrigeration and Ice Making.

1. Tests of refrigeration insulation.
2. Effect of percentages of asbestos to magnesia on conductivity.

3. Standard block-of-magnesia lagging.
4. Heat transmission of various pipes under various conditions of use.
5. Street distributing mains.
6. Corrosion of "Genuine Wrought Iron" *vs.* "Wrought Iron" (steel) pipes.
7. Effect of ice deposit on surface efficiency of refrigeration piping for low-temperature rooms.
8. "Scrubbing" inside and outside of refrigeration surface.
9. Design and test of heat radiator for test of amount of refrigeration entering a room.
10. Temperature control of cold-storage rooms.
11. Humidity control of cold-storage rooms.
12. Refrigeration—electric plant.
13. Losses due to opening boxes different periods and at different temperatures.
14. Protection of tanks against unclean foot-wear, in manufacture of ice for domestic use.
15. (See 15 for ice conveyors).
16. Refrigeration in hotels.
17. Guest-room cooling in hotels.
18. Refrigerator cars (ice *vs.* machinery).
19. Retail meat-shop ice refrigerator.
20. Tests of house refrigerators.
21. Ice-cream freezers; hand and power, efficiency in use of ice, salt, power.
22. Cooling rooms in residence in summer by ice (as suggested by Edison).

27. Ordnance in Fire Arms.
    1. Manufacture of explosives.
    2. Development of armor plate.
    3. Gun thermodynamics.
    4. Power cycle of disappearing-gun recoil and rise.
    5. The disappearing gun under analysis of mechanics of engineering.
    6. (See 11 on friction and shock absorbers).
    7. Kinematics and strength analysis of the automatic pistol, rifle, and shot gun.
    8. Radiation ribs of automatic military rifle. (See also 20).

28. Industrial Buildings.
    1. Design of the layout of buildings for the manufacture of a given product.
    2. On industrial railway, see 15.
    3. Building design for University of Missouri power plant.
    4. Cost of buildings.

5. Cost of earth excavation.
6. Concrete and steel buildings *vs.* wooden buildings as regards the shafting problem.
7. (On slow-burning construction, see 29).
8. Layout of machinery on a floor of a given factory.
9. Progress of work through a building, without doubling back.
10. (On administration of industrial establishments see 31).
11. Analysis of Columbia shoe factory.
12. Latrine design and oversight.
13. Proportioning of artificial lighting.
14. Saw tooth.
15. Round-house doors.
16. Round-house roof design.
17. Round-house floors.
18. Shop floors.

29. FIRE PROTECTION.

1. Causes of fires.
2. Chimneys.
3. Electric wiring.
4. Tests of defective wiring as producing fires.
5. Storage of inflammable material.
6. Steam-heat pipes.
7. Spontaneous combustion.
8. Friction.
9. Factory risks.
10. Prevention of fires.
11. Inspection; Missouri Fire Prevention Association.
12. Fire losses in Columbia; causes, suggestions for reduction.
13. Inspection and report upon fire risks in university buildings.
14. Inspection of old and new buildings of several classes in Columbia.
15. Reduction or increase of rates following inspection.
16. Slow-burning wooden construction of shops.
17. The automatic sprinkler.
18. Wire glass fire retardant.
19. Fire door design.
20. Automatic fire-door closing.
21. Fire extinguishers.
22. Fire-hose supports.
23. (See 21 for nozzles on fire hose, friction in hose).
24. Reducing liability for injury and death in fires.
25. Monograph on fire insurance.
26. Insurance engineering.
27. (Boston Manufacturers' Mutual Fire Insurance Co.).

28. (E. Atkinson "Fire Causes").
29. Fire insurance experiment station.

30. PROTECTION OF INDUSTRIAL WORKERS.
1. Protection of machines to prevent accidents.
2. Protection of our engine laboratory to prevent accidents, yet not to hinder its use.
3. Protection of our laboratory Bruce-Macbeth gas engine, to prevent all accidents in use by students.
4. Analysis of foundry accidents.
5. Electrical accidents in work shops.
6. Railway accidents; individual or statistical.
7. Sanitary plumbing.
8. Effect of lights on eye.
9. Lighting efficiently.
10. Law of accidents and injuries.
11. Employers' liability legislation.

31. ADMINISTRATION OF INDUSTRIAL ESTABLISHMENTS.
1. Graphical methods of plotting and analysis of data.
2. Graphical helps in apportioning time in construction.
3. Graphical progress-of-work record.
4. Graphing an organization.
5. A "line and staff" organization for shoe factory, brick works, ice plant, publishing house, department store, builder, or other Columbia large industry.
6. A "functional organization" for the preceding.
7. Authority and Responsibility:—inter-relationships and delimitation.
8. Philosophy of works management.
9. Organization by functional committees. Example: (1) Finance; (2) accounts; (3) information and statistics; (4) factory; (5) labor; (6) sales; (7) new development.
10. Division of a foreman's duties into functions, to be allotted to as many "functionalized foremen."
11. Operative economy and frequency of turning-over the capital.
12. "Dumping."
13. Sales.
14. Applications of the "exception principle" in management.
15. How frequently should various classes of statistics be graphed?
16. Unnecessary statistics.
17. Logarithmic cross-section paper in graphing statistics.
18. Analysis of cost-keeping systems.
19. Analysis and monograph on "fixed charges."
20. System of distributing "burden" or "overhead charges."
21. Comparison of wage systems, especially by curves and the analysis of the curves.

22. The theory of the "time ticket" in obtaining labor costs.
23. Costs of constructing a certain article, or a detailed part of an article.
24. Analysis of cost of a kilowatt-hour of electrical energy.
25. Influence of variations in the factors of kilowatt-hour cost.
26. Valuation of engineering properties.
27. Inventory of machines, cost, age, depreciation.
28. Influence of interest rates upon improvements.
29. The efficiency fraction in terms of labor-hours.
30. In a given establishment, what work can be removed to a "planning department."
31. A classification system for recording and for making usable the results of time studies in later planning-department work. (Tabor Mfg. Co.).
32. Analysis of the variables of (1) worker; (2) surroundings; (3) materials; (4) equipment; (5) tools; (6) motions, per Gilbreth's "Motion Study."
33. Planning the complete outfit and tools for some operations or "task."
34. Rearrangement of machines to secure better routing of work.
35. Making an "instruction sheet" for some operation, including time for each element.
36. The proper elements in an analysis of an operation.
37. Efficiency studies of university building operations.
38. Analysis of setting-up work in a machine.
39. Experimental time records on work.
40. Determining time and cost for (*a*) handling the raw material, (*b*) setting up the work in the machine, (*c*) machining, (*d*), removing the finished product, (*e*) making machine ready.
41. The care of materials; (*a*) design, (*b*) specification, (*c*) tender, (*d*) selection, (*e*) test, (*f*) custody, (*g*) use, (*h*) inspection.
42. The value of materials.
43. Equipment and personnel analyzed like materials.
44. Standardization of implements.
45. Standardization of methods.
46. Convenient locations of tools at a machine.
47. The care of tools, inside and outside of tool room, messenger service.
48. The design of a move-order system.
49. Works transportation; costs while in motion *vs.* of loading and unloading.
50. A system of classification numbers on shop orders. (Ennis, p. 30).
51. Cutting metals; tests of speeds, tool shapes, steels.

52. Development of a science of some trade or occupation, simple enough to be completed in time available.
53. Time and motion studies of any sort of occupation, trade, labor, business, profession,—existing in Columbia.
54. Efficiency study of sweeping, and of brooms.
55. Moving-picture studies of work.
56. Fatigue studies.
57. Most efficient size or weight of unit moved.
58. Necessary proportions of time for rest and work in various occupations.
59. Experimental psychology in the placing and selection of workmen. (Hugo Münsterberg's "Psychology and Industrial Efficiency").
60. Finding one waste, and tracing all its causes.
61. Observing, recording, analyzing and comparing any train of antecedent-consequent facts.
62. The influence of wrong units of comparison, when attempting to measure the comparative efficiences, methods, departments, officers, plants, etc.
63. Stores.
64. Topics relating to engineering education, industrial education, trade schools, apprentices, education of employees, organized labor, organized capital, unorganized public, governmental oversight and control.
65. New Zealand practice in the relationships of labor, capital and the public.
66. Recent industrial legislation.
67. (See 18 for locomotive coal-premium system).

32. Maintenance and Depreciation of Plant and Equipment.

1. Curve of depreciation of a given machine, exclusive of "getting out of date" or "obsolescence."
2. Curve of future depreciation of a given machine solely due to the past history of progress in methods of doing the work that this given machine is doing now.
3. Depreciation of power plant equipment.
4. Monograph on the science of depreciation.
5. Inspection of equipment.
6. Applications of the principle of "prevention of breakdowns."
7. Breakdown insurance *vs.* interest, depreciation, and obsolescence of duplicate idle equipment.
8. A study of depreciation of machine classes, (*a*) time and the elements, (*b*) wear in service, (*c*) obsolescence.
9. Causes for annual revisions of probable life.
10. Depreciation and betterments in replacement.

11. (See 31 for prevention of breakdowns).
12. (See 18 for depreciation of railway equipment),

33. Relations with Architects.
34. Relations with Metallurgists.
35. Relations with Civil Engineers.
Coöperation with a C.E. student in the production of a joint thesis, as in cement, excavation and dredging, water power, industrial buildings.

36. Relations with Mining Engineers.
37. Relations with Chemical Engineers.
Coöperation with a Ch.E. student in the production of a joint thesis, as in cement.

38. Relation with Electrical Engineers.
Coöperation with an E.E. student in the production of a joint thesis; the E.E. handling the electrical side and the M.E. handling the mechanical side.

5. Thesis Subjects from Another Engineering School.

1. Application of Steam Engine Indicator to a Locomotive.
2. An Experimental Study of the Balancing of the Action of the Reciprocating Parts of a Locomotive.
3. Action of Reciprocating Parts on the Crank Pin Pressures of Certain Engines.
4. The Slipping and Friction of Oak-tanned Leather Belts. Strength and Elasticity of Shafting under Combined Twisting and Bending.
5. Design for a Hot Forge Nut Press, with Experiments on the Shearing Strength of Hot Iron.
6. An Experimental Study of the Surface Condenser.
7. Pressure on Lathe and Planer Tools.
8. Transmission of Power by Rope Gearing.
9. Design for Arrangement of Machinery in a Worsted Mill.
10. Experimental Investigation of Flow of Steam Through a Tube.
11. Errors of the Steam Engine Indicator.
12. Tests on Pumping Engines with Reference to Cylinder Condensation.
13. Design for a Mine Hoisting Plant.
14. Experiment on the Steam Injector and Apparatus for Determination of Velocity of Delivered Water.
15. Tests of the Strength and Other Properties of Rope.
16. Experimental Investigation of Proper Angles for Cutting Tools.
17. Experiments on Strength of Pulleys, Keys, and Set Screws.
18. Experiments on the Performance of a Windmill.
19. Experimental Study of the Deflections of Parallel Rods at Different Speeds.

20. Strength of Eyes as used in Boiler Stays.
21. Experiments on Strength of Cast Iron Gear Teeth.
22. Tests on Tensile Strength and Modulus of Elasticity of Hard Drawn Copper Wire
23. Experimental Investigation of Friction and Breaking Strength of U. S. Standard Bolts and Nuts.
24. Design for a Pneumatic Holding Machine for Car Wheels.
25. Experimental Investigation of Slip of Leather Belts on Cast Iron Pulleys.
26. Tests on Lift and Discharge of a Safety Valve.
27. Design for an Automatic Rack Cutter, including Some Tests on Milling Cutters.
28. The Design, Construction and Testing of a Torsion Dynamometer.
29. Experiments to Determine Effect of Repeated Bending on Wrought Iron and Steel.
30. Design of the Reciprocating Parts and Valve Motion of a Special Form of Compound Engine.
31. Experimental Determination of the Modulus of Elasticity of the Skin of Cast Iron Beams.
32. Tests on a ''Sturtevant'' Steam Hot Blast Apparatus.
33. Experiments to Determine the Amount of Moisture that Steam will carry.
34. Experiments on Friction of Bolt Threads.
35. Explosion of Gases in a Closed Vessel.
36. Experiments on the Value of the Steam Jacket on a Direct-Acting Pumping Engine.
37. Tests on Elevators.
38. Tests upon Flange Coupling under Repeated Stresses.
39. Investigation of the Action of Steam Separators.
40. Experiments to Determine the Coefficient of Discharge from Pipes through Branches and Side Orifices. (Cooling tower?)
41. The Distribution of the Pressure Exerted by Cast-iron Spring Piston Rings.
42. Tests on the Bursting Strength of Steam Pipe Fittings.
43. Location and Effect of Blowholes in Steel Boiler Plate Rolled from Bottom Poured Ingots.
44. Design for a Boiler Shop.
45. Experimental Investigation of the Action of a Steam Engine Governor.
46. Friction Theory of Belting.
47. Automatic *vs.* Hand Stoking on a Galloway Boiler.
48. Shaft Coupling.
49. Strength of Telegraph Wires under Different Conditions.
50. Experiments on Shearing Strength of Cast Iron.
51. Errors in the Cards of the Steam Engine Indicator due to the Length and Size of the Pipe Connections used therewith.

52. Design for a Rock Crusher.
53. Tests on an Evaporative Surface Condenser.
54. Action of a Steam Rock Drill under Varying Pressures.
55. Tests of Tensile Strength and Elasticity of Malleable Iron.
56. Effect of Jackets on a Simple Engine.
57. Determination of the Pressure Required to Form Belt Heads.
58. Determination of the Variation in the Density of Steel under Stress.
59. Study of the Frictional Resistance of Shafting.
60. Investigation of the Stress in Cast-iron Pulley Arms and Rims.
61. Experimental Investigation of the Distribution of Power in a Modern Newspaper Plant.
62. Action of Wind Pressure on Surfaces.
63. Tests on Various Types of Steam Reducing Valves.
64. Experimental Study of the Application of Compressed Air to Shop Uses.
65. Variation of Coefficient of Friction between Leather Belting and Cast Iron at Different Speeds of Slip.
66. Loss of Pressure of Air Flowing Through Small Pipes.
67. Investigation of the Distribution of Power in a Cotton Mill, and a Study of Resulting Losses in Transmission.
68. Wear of Brake Shoes of Different Materials Relatively to the Wear on the Wheel Tires.
69. "Slip" and "Creep" of Leather Belting.
70. Experimental Investigation of the Action of the Pendulum Governor.
71. Experiments in Hardening and Tempering Steel.
72. Fly-Wheel Calculations.
73. Relative Efficiency of Bearings and Lubricants of a Spinning Frame under Mill Conditions.
74. Design of a Central Heating Plant.
75. Design of an Oil Machine.
76. Comparative Strength of Standard Screws and Cylindrical Rods of the same Root Diameter.
77. Design of a Locomotive Repair and Erecting Shop.
78. Effect of Different Initial Pressures on Explosive Mixtures of Gas and Air.
79. Relation between Draft and Temperature in Chimneys.
80. Friction of Steam in Elbows and Bends.
81. Tests of the Heating and Ventilating Plant of a Theatre, combined with a Design for a System of Ventilation of an Office Building.
82. A Study and Design of Steam Meters.
83. Design of an Experimental Yarn Tester.
84. Effect of Heating, Quenching in Oil, and Subsequent Annealing, on the Physical Properties and Microstructures of Steel Castings.
85. Tests on Heating Cars by Steam from the Locomotive.

86. A Method of Testing a Pneumatic Chipping Hammer.
87. Tests of a Simple and of a Compound Traction Engine.
88. Oil Separators.
89. Tests on Air Filters.

6. Thesis in Electrical Engineering.

Topics Suggested.

1. General.
    1. Choice of Frequency.
    2. Pure Sine Waves.
    3. Effects of Distorted Waves.
    4. Magnetic Circuits of Various Forms and Dimensions.
    5. Distribution of Flux in D. C. and A. C. Circuits.
    6. Sparking; Its Causes and Effects.
    7. Effects of Alternating Current upon Reinforced Concrete.
    8. Investigation of the Laws of Friction.
    9. The Cost of Power.
    10. Selection and Arrangement of Useful Data.
    11. Study of Plants at Coal Mines.
    12. Study of Very Small Hydro-Electric Plants.
    13. Gyroscopic Balancing.
    14. Magnetic Losses in Iron.
    15. On the Law of Eddy Currents.
2. Measurements.
    1. Instrument Transformers.
    2. Transformer for Measuring Large Currents.
    3. Electrical Methods of Measuring Speed.
    4. Slip Meters.
    5. Accelerometers.
    6. Methods of Taking Alternating Current Waves.
    7. Resonance Analysis.
    8. Phase Measurements.
    9. Investigation of Induction Type Meters.
    10 Measurement of High Voltages.
    11. Ampere Hour Meters.
    12. Absorption Dynamometers.
3. Materials.
    1. Commercial Methods of Testing Iron.
    2. Magnetic Method of Testing for Imperfections in Iron.
    3. Tests on Insulating Materials.
    4. Heat Conductivity of Insulating Materials.
    5. Study of Wire Voltage Insulators.
    6. Formation of Copper Compound on Surface to serve for Insulation.
4. Generation.
    1. Comparison of Prime Movers.
    2. Contact Resistance.
    3. Commutation of Direct and Alternating Currents.

4. Heating of Coils.
5. Do Cross Turns have Demagnetizing Effect?
6. Prevention of Hunting.
7. Study of Efficiencies and Losses of Dynamos
8. Regulation of Synchronous Machines.
9. Effects of varying Voltage upon the Operation of Induction Motors.
10. Compounding Generating Station.
11. Design of Electric Plant for the University of Missouri.

5. TRANSFORMATION.

1. Experimental Tests of Transformer Theories.
2. Theory of Straight Core Ferric Inductances.
3. Multiphase Transformer Connections.
4. Effects of Residual Magnetism upon the Exciting Current of Transformers.
5. Transformation of Phase.
6. Direct Current Balances.
7. Study of Rectifiers.
8. Study of Boosters and Batteries.

6. TRANSMISSION AND DISTRIBUTION.

1. Systems of Electrical Distribution.
2. Design of a Distribution System.
3. The Edison Three-Wire System.
4. Network Design.
5. Comparison of Methods for Regulation of Voltage.
6. Design of an Automatic Voltage Regulator.
7. Automatic Transformer Switch.
8. Construction of a Phase Regulator.
9. Design of Transmission Lines.
10. Power Transmission by Direct Currents.
11. Protection of Overhead Lines.
12. Installation of Cables.
13. Fire-proof Wiring and Switchboard Construction.
14. Grounding the Neutral.
15. Analysis of Losses in a System.

7. UTILIZATION.

1. The Application of Motors.
2. Use of the Series Alternating Current Motor for the Electric Drive.
3. Power Required by Various Machines.
4. Comparison of Different Electric Lights.
5. Study of Illumination.
6. Study of Lighting for Gymnasium.
7. Modification of Electric Candle for Alternating Currents.
8. Electric Furnaces.
9. Electric Forging and Welding.
10. Laboratory Heating Devices.
11. Use of Electricity in Mining.

8. Electric Railway Engineering.

1. Choice of Types of Motors for Traction.
2. Study of Train Motion.
3. Study of Train Resistance.
4. Alternating Current Motor.
5. Regenerative Control.

Discussion.

Professor H. Wade Hibbard: I have presented this as one school's definite way of bringing to the attention of the students during the semester before they become last-year men the fact that a thesis is to be expected and that they should get ready for it by thinking about it during the semester and during the summer. They will thus be able to choose a definite subject within a month after they return to school in September, and to lay out their plans so carefully and read so extensively during the one credit-hour of the first semester that they will start actual work in a detailed and thorough fashion at the very beginning of the second. The number of credit-hours allowed for the thesis in the second semester of the last year is a minimum of two, that is, $\frac{2}{15}$ of the semester's work. The maximum has not yet been decided upon nor reached. We are feeling our way toward what may be the maximum. With the reorganization of the school of engineering, we include all courses given in mechanical engineering in our previous four-year course, while still allowing some twelve credit-hours of elective in the three-year course. I do not suppose that these hours will ever be used in the thesis. We are feeling our way toward what we hope is going to be an increasingly valuable portion of the mechanical engineering curriculum.

Professor J. J. Flather: The subject of thesis is one that has received careful attention here at the University of Minnesota. Last year an investigation was carried on by Professor Martenis, of the mechanical engineering department, to learn to what extent theses were required in the various institutions, and also how much credit is given for them. In the mechanical engineering department at the University of Minnesota we require no specific number of hours the first semester, but we do require essentially the same preliminary preparation for theses as is required by Professor Hibbard. All preparation

work must be done before the Christmas vacation, but the student heretofore has not had any credit for that work. He has been required to do his preliminary reading and planning so that by the time the Christmas vacation came round he was ready to do some work during that vacation. In the second semester we require three credit-hours, that is, we expect a student to put in at least six hours per week on his work during that semester. As a matter of fact the time spent invariably exceeds this amount. We merely give him credit in our curriculum for three hours out of a total of perhaps eighteen or twenty.

After the investigation above referred to the mechanical engineering department recommended that one hour credit per week be allowed for theses in the first semester, and that in the second semester a total of five credit-hours be spent upon the thesis and elective subjects combined. This is somewhat flexible and the five hours can be divided as required. This arrangement is valuable because it permits a student to elect a subject closely articulated with the thesis for which ordinarily credit could not be given in the thesis itself and yet it might have great utility to him.

It also permits a man to spend the full five credit-hours on the thesis if this should be thought advisable, and on the other hand, if the conditions should seem to indicate that a lesser amount of time on the thesis proper and a greater amount on some collateral subject should be the best arrangement, this would be permitted without his having to obtain special permission from the faculty.

In a great many cases too much time has been put in on thesis problems. A student is apt to think that the thesis is the principal thing in his senior year, and accordingly neglect his regular studies. He is very prone to "cut" this lecture or that recitation in favor of thesis work.

As a result of a study of the curricula of leading schools including such institutions as The Case School, Columbia University, Iowa State University, Lehigh University, the Massachusetts Institute of Technology, the University of Michigan, the University of Nebraska, the Ohio State University, Rose

Polytechnic Institute and the University of Wisconsin, the average credit for thesis work by the senior engineering students is known to be 3.55 hours. Electrical students were given 3.94, and mechanical students 3.25 semester credit-hours during the year. This shows that, after all, there is not the preponderance of hours spent on the thesis work formerly so spent.

Professor Hibbard: Will Professor Flather kindly interpret these figures for us? That is what portion of a student's total time per week is represented by the figures given?

Professor Flather: Those figures are based on sixteen or eighteen credit-hours per week. It should be understood in this connection that a number of institutions included do not require any specific time to be spent on thesis work. Columbia University, for instance, does not require it of "mechanicals," and for "electricals" it is optional. Certain students at Cornell University may take thesis work, if particularly qualified for research work. Then it is expected that they will, under the guidance of the head of the department concerned, select suitable theses subjects. In this case the student may spend four credit-hours on his thesis. For other men it is considered wiser to spend the time on some other study. At the University of Michigan the thesis is not required, so also at the University of Nebraska while thesis work is a part of the engineering curricula a student may elect some other subject, if deemed advisable by the department concerned. The thesis is not required at the Sheffield Scientific School in the three-year course, but in the five-year course ten hours are required. Professor Hibbard's suggestion of one credit-hour in the first semester with a minimum of two in the second is good, but I should limit the number of hours for fear that the thesis might be considered as unduly important. The undergraduate student should confine his attention rather to his study work because research work is not generally suitable for undergraduate students.

Dean Adolph Shane: The subject of the theses has been "bobbing up" for some time. Teachers of engineering are perplexed to determine whether or not such work is valuable. If the thesis is considered to mean only a subject for original

research study, then the value to the student may be considered doubtful.

Dean P. F. Walker: I wish to go on record as one who is still in favor of the thesis. I do not, however, care to see more than a total of three credit-hours, each representing three hours per week of actual work, the total time being divided between the first and second semester. There are two reasons why I believe very thoroughly in the thesis. In the first place it is one of the best methods by which we may teach the student to think for himself, to really think a problem through. For that reason the responsibility for the work should be thrown upon the student. Second, it is worth while for the student to have and preserve a record of one fully completed task or problem, one into which he has put his best thought and work, and one which will stand in the record as representing his own work.

From what I have said it follows that I believe that the thesis should be on a subject involving original investigation whenever that is possible. This kind of work often arouses the student to unusual effort and has a certain value in bringing him to a realization of his own powers and in enabling the instructor to gauge those powers.

Professor Hibbard: With regard to Professor Flather's proposed plan that the thesis and electives should be permitted in the first and second semester, I want to ask who decides how much time shall go into the thesis and how much into the elective, the student or some member of the faculty?

Professor Flather: Our practice is that it must be determined in consultation with the head of the department.

Professor Hibbard: Professor Flather represents a large number who believe that research is not suitable for undergraduates. Going back to my previous remarks I would repeat that by having, as we now do, two years work in the college of arts and sciences, and three years in engineering we gain twelve credit-hours, that is, $^{12}/_{15}$ of one semester for additional work. With the help of the large number of manual-training high schools which are doing excellent shopwork we shall gain at least eight more. In other words, our new curriculum in mechanical and other branches of engineering

will make the last-year men more mature than the seniors whom we had under the four-year course. They are by $^{12}/_{30}$ or $^{20}/_{30}$ of a year nearer to being what might be called graduate engineering students.

In the atmosphere of post-high school training, they will have had four years before their last year. Furthermore, such a last year is of as much greater value than a master of arts' year, as any engineering course is of greater research educational value than the usual four years' Arts course of American colleges.

I want to urge farther that the thesis subject should be a small one. A mistake is made when some vast problem like designing a power plant for the Twin City railway, or an important test of a plant is attacked. Possibly the reason for a student's taking too large a subject has been the absence of such a list of suggested topics as I have been asked to furnish in connection with this paper, a list of 1,500 topics. If you make use of this list with your students next year you will find some things put down in a very minute fashion, minute portions of large subjects.

Professor Shane said that the choice of a subject should be left to the student. I don't suppose he meant by that that the student could actually choose his subject irrespective of what the professors think he ought to do?

One of the speakers suggested that research work does not amount to much. You will notice that I read: "Let the student so plan the work that he may hope that his results will be accepted and paid for and published by an engineering paper." We have already had some of that recognition at Missouri. I submit that, if an engineering journal in good standing will pay for and devote several pages to the results of a thesis investigation, that research has value to the profession.

Dean Shane: No, that was not my idea. The work should be always subject to the approval of the head of the department. I merely make the point that the student is more interested in a subject of his own choosing.

Professor Hibbard: I agree with you decidedly.

CIVIL ENGINEERING THESES.*

BY C. E. SHERMAN,

Professor of Civil Engineering, The Ohio State University.

We regard theses as one of the most important subjects in our course. It would be well if each graduate could prepare several theses in place of one, or at least one in each of the following branches of civil engineering:

1. Complete structural design from inception to maintenance.
2. Much experimentation with digest of results and conclusions.
3. More or less of a literary effort.
4. Pure or applied mathematics.
5. Public engineering projects.
6. Engineering problems largely involving economics.

Of course, time does not permit such a program to be carried out in modern college courses, that is if each thesis completed were really worthy of the name. There is time for only one in the graduating year, and in his earlier years the student has not had sufficient training to enable him to prepare a real thesis. But that it would be highly beneficial to prepare theses in each branch above suggested is shown in the following paragraphs.

1. Structural design in steel is perhaps more easily adaptable to thesis subjects than any other field. Steel highway or railway bridges, viaducts, water towers, gas holders, tall buildings, etc., all furnish problems, the conditions of which may usually be concisely stated and the solving of which furnish exercises in the precise work which is especially needed

* Attention is particularly directed to a booklet entitled "Rules for Thesis Work," printed by the civil engineering department of the University of California and referred to in the February, 1914, BULLETIN of the Society.

by the young engineer. Steel is the structural material *par excellence* for thesis subjects.

2. Civil engineering courses, as compared with those in mechanical and electrical engineering, are deficient in the training furnished by extensive experimental work. This weakness can be corrected by choosing a thesis in a civil engineering subject which will supply practice in rigging up apparatus and overcoming obstacles that arise in using it; in gathering experimental data at first hand; in determining the degree of accuracy attainable, and in digesting results and presenting conclusions. Such theses as the experimental determination of weir coefficients, of the flow in pipes and bends, of measuring the runoff of a stream, experimental studies in strength of materials, testing and reporting on the road materials of a county, etc., furnish training in experimentation.

3. By more or less of a literary effort is meant, for example, a codification of road laws with suggested legislation, or a similar digest relating to county surveyors' duties, or to the practice of civil engineering in general, with suggested legislation, etc. Such a theme would give the practice in using English so badly needed by engineering students, with collateral benefits from the study of legal phraseology. No mathematics, drawing, or experimentation, need be required in such a thesis, and yet its value may be as great as any other.

4. Some of our graduates have made thesis researches along mathematical lines in which they were especially interested. A theoretical comparison of formulæ for columns, or a study of wind stresses in tall buildings, suggests some of the opportunities under this caption. In general however, such theses are better accompanied by experimental investigation, for the engineer is primarily an applied scientist.

5. Public engineering projects furnish fruitful themes for theses. The installation of sewerage systems in small towns and of sewage treatment plants, water supply projects, street and highway improvements and civic betterments of many descriptions, involve the formulating of legal preliminaries

and the preparing of plans and specifications, and give practice in estimating costs of materials and labor.

6. While economics is involved in practically every engineering enterprise, there are some theses that bring this subject to attention more forcibly than others. The economics of motor trucking, the reconstructing of an old railroad to meet new operating conditions, the rearrangement of a factory which has outgrown its facilities, a report on a hydro-electric proposition including an investigation of market conditions (which latter is so often the crucial point in such a project), all forcibly emphasize the part economics plays in engineering.

The above six topics by no means exhaust the available fields, nor do the examples cited under each caption sufficiently display the possibilities under each. The student may have had experience along special lines which he wishes to investigate farther, and may readily take his thesis in such subject. A study of movable dams, of reservoir control of a stream, of a waste disposal plant, of bituminous highway materials, or another subject which has not been extensively treated in his regular course, may be a proper subject for a thesis, if the student is especially interested in any one of them.

Theses afford the student an *extended* individual exercise in correlating his information, in testing and developing his acquired powers, in reaching neatness, definiteness and completeness, in using written and graphic language, and in methods of presenting his ideas formally to the public, with the benefit of a frank criticism on his success in these directions by a qualified and impartial judge. To be sure other college exercises afford opportunity in the directions noted, but they are not sustained enough to give any lasting satisfaction.

Assuming that the student has chosen a subject in which he is thoroughly interested—and his own practical experience together with an explanation of the breadth and possibilities of the fields first listed above by his instructor, can arouse such interest—he can spend time on his thesis more profitably perhaps than on any other single subject in his course.

Collateral advantages of theses are that they may afford opportunity to review a subject of his course which for any reason the student did not thoroughly understand. Theses may lend elasticity to an otherwise necessarily rigid course by supplying an elective. Theses may also advance knowledge by original research. This last, however, is not the main object of a thesis. If a contribution to the world's knowledge can be made in a thesis so much the better, but a thesis should primarily make a contribution to the student's knowledge and power.

Our students have always taken great interest in thesis work, and they won first place on averages against all departments of the colleges in the country in the four thesis contests conducted by the *Engineering News* from 1892 to 1895. The writer used his own graduating thesis to clear up his ideas on a certain phase of drafting, and although such a theme (lying chiefly in field No. 3 above) is usually not so valuable as theses in other fields, still it was something of a lasting satisfaction to him to see the thesis when finished adopted as a text-book at a number of universities.

THE GRADING SYSTEM OF THE UNIVERSITY OF MISSOURI.

BY A. LINCOLN HYDE,

Associate Professor of Bridge Engineering, University of Missouri.

The grading of students of all classes from the kindergarten to the university seems to be a necessary evil. Evil it certainly appears to be regarded by some, and the most disagreeable of the many tasks a teacher is called upon to perform by many. Necessity, nevertheless, it has proved to be for the award of prizes and honors, and it does serve as a stimulus for some, as well as a prod for other students.

Usual Grading Methods Unscientific.

In an article on "Examinations, Grades, and Credits," published in 1905, Professor J. McKeen Cattell calls attention to the scantiness of literature on college grades, and says that it seems strange that no scientific study of the subject of consequence has been made. He states that apparently grades are assigned for moral traits or general impressions as much as for ability and performance. He cites Dr. Galton, Professor Pearson, and others as authorities for the statement that the qualities of ability and performance are distributed in accordance with the curve of error.

In "A Guide to the Equitable Grading of Students," published in 1906, Professor Winfield Scott Hall states that his study in this field was undertaken in response to the inquiry, "Does science offer any solution of the problem of grading?" He regards the percentage system as folly, because it makes slavish work for the teacher, and gives the student false values. The mark, which is merely the teacher's estimate, becomes the student's goal.

Professor Hall summarizes his conclusions from his study of the subject as follows:

1. The marking of students is a measure of psychic function, and yields biological data.

2. All biological data, including student rating, are distributed about a median value in conformity with the law of distribution of biological data, which law is demonstrated to be represented in the binomial curve.

3. Average classes of students, doing honest work and marked equitably, will yield results which when tabulated should conform to the binomial curve; *i. e.*, the number receiving medium marks should far exceed the number receiving high or low marks.

Investigation Shows Wide Variation.

During the year 1907 Dr. Max Meyer, professor of experimental psychology in the University of Missouri, made a study of the grades assigned during the preceding five years by forty teachers in the institution. About the year 1902 the university faculty had voted to adopt the grades *A, B, C, D* and *E*, *A* signifying the highest rank obtainable and *E* indicating failure. The grade *D* meant that the student had received a "condition" which was to be removed within a reasonable period of time by the performance of additional work or by another examination, in default of which he was to be considered as having failed in the subject.

Dr. Meyer was satisfied that if the number of cases considered was sufficiently large the curve of ability and performance should approximate the probability curve. His investigations revealed a wide variation. As unremoved conditions were treated as failures, he grouped the grades *D* and *E* under a single head, *F*, in his records. At one extreme he found that one teacher, for 623 students included in 29 classes, had given 55 per cent of *A*'s, 33 per cent of *B*'s, 10 per cent of *C*'s, and 2 per cent of *F*'s; while at the other extreme another teacher, for 1903 students in 12 classes, had given 0.5 per cent of *A*'s, 11 per cent of *B*'s, 60.5 per cent of

C's, and 28 per cent of *F*'s. Obviously something was wrong. Assuming that the students had done or were held to honest work, these deviations from the probability curve must have been the result of general impressions. The teachers could scarcely be blamed for the extreme variations. The faculty had not given the matter any great amount of thought and had left the grades undefined. It was assumed that each teacher would know intuitively for what the different grades stood. The results were startling.

Missouri Inaugurates a Scientific Method.

Realizing the desirability of standardization Dr. Meyer read a paper on the subject of student grading before a special meeting of the teachers of the University, and followed this up with another on the same subject which was presented before the Scientific Association. His exposition was so clear and his arguments so convincing that the grading system now in use was shortly thereafter adopted by the university faculty.

Briefly stated the system is as follows: In classes sufficiently large to exclude accidental variations, approximately 50 per cent shall receive the grade *M* (medium); to the great majority of the 25 per cent above *M* the grade *S* (superior) shall be given; and to the few most excellent students the grade *E* shall be assigned; the majority of the 25 per cent below *M* shall receive the grade *I* (inferior), and the minority shall be given the grade *F* (failure).

The question of adhering to the old system of letters, *A, B, C, D,* and *E* was discussed at length and it was believed that there would be less resulting confusion in making the change if new letters were used, and it was decided to adopt the letters *E, S, M, I,* and *F*.

Varying Quantity of Credit on Basis of Quality.

Believing that quality of work should be recognized otherwise than by empty honor, it was agreed that such faculties as so desired should be permitted to give excess credit for

excellent and superior work, and that inferior work might be given reduced credit, no credit of course being allowed for failure. It was at first decided to allow 30 per cent excess credit for *E*, 10 per cent excess for *S*, and to deduct 20 per cent for the *I* grade Later the excess for *S* was changed to 15 per cent. A student in the college of arts and science making all *E* grades may therefore be graduated in three years; one whose average grade is *S* or above may finish in three and one half years; while a student whose average grade is *I* must spend five years in obtaining sufficient credit for the A.B. degree.

Results Achieved.

The system has been in use since the summer session of 1908 and the results may be said to be most gratifying. In the latest cumulative report showing the grading of sixty-one teachers of under courses (freshman and sophomore), and including the period beginning with the second semester of 1909–10 and ending with the first semester of 1912–13, one teacher is credited with 10 per cent of *E*'s, the next highest percentage being 6, which is reported by three teachers. This is quite a decided drop from 55 per cent which was shown under the old system. A single teacher reported no *E*'s for the under courses. It is interesting to note that the average percentage of *E*'s for these courses is 3.38, which seems quite reasonable. Compared with the suggested probable total of *E*'s and *S*'s of 25 per cent, experience has given 22.29 per cent, the great variations being one of 34 per cent, one of 30 per cent, one of 12 per cent, and one of 13 per cent. For the *M* grades the average is 52.49 against the 50 per cent suggested, with the great variations of one of 70 per cent, one of 64 per cent, one of 35 per cent, and one of 38 per cent. The average total of *I*'s and *F*'s is 25.22 against 25 per cent, the greatest variations being one of 44 per cent, one of 41 per cent, two of 12 per cent, and one of 14 per cent. The system requires that the minority of the lowest 25 per cent shall be marked *F*, and the report for under courses places the figures for this grade of students at 7.32 per cent.

For upper (junior and senior) and professional courses the figures differ slightly, the comparison with the under courses being shown in the table below. Among the sixty-four teachers represented in the upper and professional courses, four are high markers with 18, 14, 13, and 10 per cent of *E*'s, but even these are considerably below the 55 per cent of the old system. There are also two low graders with 19 and 11 per cent respectively charged against them.

It should be stated that in the report for under courses, no teacher with fewer than 500 grade-hours, and in the report for the upper and professional courses, no teacher with fewer than 250 grade-hours is included.

COMPARATIVE PERCENTAGES.

	E	*S*	*M*	*I*	*F*
Under courses	3.38	18.91	52.49	17.90	7.32
Upper and professional courses	4.73	22.84	53.49	15.13	3.81

Many teachers, perhaps the majority, believe that courses should be adapted to the average students in the various classes. This permits the better students to prepare their lessons in a comparatively short time and enables them to do wider reading in the particular subject or to engage in other broadening work, and at the same time allows the inferior students to get something out of the course.

Some of the low markers attempt to explain their percentages by saying that their students are insufficiently prepared, but many educators will agree with Dr. Meyer in his assertion that these teachers are usurping rights which are not justly theirs, and that the proper authorities should readjust the entrance requirements when it has been clearly demonstrated that such change is necessary.

Some of the high markers argue that they are extremely particular about admitting students to their classes, but it would seem that it would require a very large number of exclusions to account for the difference between 4.73 and 18 per cent, and it is doubtful if a teacher is warranted in pre-

judging and excluding on meager evidence students who might get considerable value out of his courses.

Proper Number of Grades.

As to the most desirable number of grades to assign, some teachers are satisfied with two; *passed* and *not passed*. Some institutions, such as the University of Kansas, use three; Harvard University and many others use five; and Reed College, after a careful study of the subject of grading by President Foster, decided on ten.

To minimize friction and increase efficiency the number of working parts of a machine should be kept as low as possible. Many will agree with Professor Winslow H. Herschel that the odd number of grades is preferable. Most teachers will concur in the belief that approximately 50 per cent of any large number of students are of *average* ability, and that the balance is about evenly divided between those *above the average* and those *below the average*. But three divisions are hardly sufficient for the purpose of awarding prizes and honors. A very small number of students possess exceptional ability and work up to their capacity, and a few are mentally deficient or lazy, or both. To provide for these it would seem that five grades are sufficient for the majority of educational institutions.

Subjective and Objective Grading.

Teachers should keep in mind that they are grading for ability, and ability as demonstrated by performance rather than ability as determined from general impressions. Tests should be of such a character as to enable the teacher to draw correct conclusions with the least possible amount of fatiguing labor. Some teachers have been known to shirk the reading of long and numerous examination papers, and to rely almost entirely on general impressions. This is of course manifestly unfair to the students who should have the right to feel that they are being graded for their ability as evidenced by their performance.

In mathematical and engineering courses subjective and

objective valuations may be combined. In such subjects as experimental and educational psychology, chemistry, and zoology the Ebbinghaus method of conjectural examination has been found to check with other methods, and to give effective results with much less labor on the part of the teacher. Professor Karapetoff has expressed himself as well pleased with this method as used in his classes in electrical engineering at Cornell University.

Perhaps the simplest and best way to arrive at conclusions in using the grading system as adopted at the University of Missouri is to rank the students (using the numbers 1, 2, 3, 4, 5, . . .) for each test, quizz, or examination. If it is desired to give any special weight to any particular test, the rank numbers for that test may be multiplied by the proper coeffi-

FINALS FOR CLASS OF TWENTY-FOUR.

Name	Recitations	Quizzes	Reports	Examination	Totals	Diff.	Grade	P. C.
H	1	1	2	3 (1)	7		*E*	4.17
J	4	6	4	9 (3)	23	16	*S*	
I	3	2	6	12 (4)	23	0	*S*	16.66
O	2	8	7	6 (2)	23	0	*S*	
F	5	4	1	15 (5)	25	2	*S*	
N	5	3	3	24 (8)	35	10	*M*	
A	8	5	5	21 (7)	39	4	*M*	
V	7	10	12	18 (6)	47	8	*M*	
G	10	17	8	30 (10)	55	8	*M*	
B	13	14	9	27 (9)	63	8	*M*	
M	9	11	11	36 (12)	67	4	*M*	
E	12	11	17	33 (11)	73	6	*M*	54.17
T	18	9	14	39 (13)	80	7	*M*	
W	11	16	10	54 (18)	91	11	*M*	
C	15	18	18	42 (14)	93	2	*M*	
X	14	15	22	48 (16)	99	6	*M*	
P	16	13	16	57 (19)	102	3	*M*	
D	21	19	15	51 (17)	106	4	*M*	
L	24	23	24	45 (15)	116	10	*I*	
R	20	17	20	60 (20)	117	1	*I*	
U	19	20	13	66 (22)	118	1	*I*	20.83
Q	17	24	22	63 (21)	126	8	*I*	
K	22	18	20	66 (22)	126	0	*I*	
S	22	21	21	72 (24)	136	10	*F*	4.17

cient, as shown below where examination rank numbers have been multiplied by three, thereby giving equal weight to examination and term work. To ascertain final grades summations of the rank numbers for the several students may be made and these summations may be arranged in order according to size. By keeping the prescribed percentages in mind and observing the differences in summations, the finals may quickly be derived.

Conclusions.

The various studies which have been made show that, when a sufficiently large number of grades in any institution is considered and the values are tabulated, the resulting curve approximates the curve of probability. It merely remains then to convince those teachers whose marks deviate greatly from the average marks of all other teachers in the institution that they should make an effort to ascertain the reason for such deviations, and if they are unable to discern and remove the cause, or if they are unable to account for their differences, they should be required to submit their rankings for their various tests to the chairman or head of the department for the assignment of the grades.

The system in use at the University of Missouri was adopted for the purpose of bringing about greater uniformity in the grading of the students. There has been a decided advance toward the desired end. There are a few straggling deviations corresponding to what are known among scientific observers as huge errors, and in judging the system we may emulate scientific computers in rejecting these as due to incorrect conclusions or to extraordinary coincidences.

Any system must be used with sound judgment, without fear or favor, and it is believed that this system so used is the best that has thus far been devised for the equitable grading of students for ability and performance.

In closing it may be pardonable to quote: "The most perfect system of rules to insure success must be interpreted upon the broad grounds of professional intelligence and common sense."

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Discussion.

Professor E. F. Chandler: Attention should be called to the difficulty of imposing uniformity in a marking system on members of a faculty. We have had some experience of this at the University of North Dakota during the past ten years. We tried, for a time, to give surplus credit for high standing,

but have now discarded the plan. The difficulty in using it is this; that certain students will pass or fail under any system. The amount of work expected of them is also fairly well determined or standardized. However, among those that pass there is a marked distinction between those of high and those of low standing; this distinction has not been reduced to standard terms. Unless considerable pressure is brought to bear upon them to see that there is reasonable uniformity among departments some teachers will give a disproportionate number of high standings. This practice attracts a certain sort of students into these courses, partly to secure the credits, although this tendency is perhaps an unconscious one. On the other hand some teachers are proverbially low markers. While they will pass a reasonably large proportion of their students they give them excessively low marks. Theoretically I approve the principle of giving excellent students surplus credit for good work. This principle is pedagogically correct. An "*A*" student is worth twice as much as one who barely passes, so that the Missouri system, if it can be operated properly, embodies correct principles. The chief difficulty that we found was in securing operation equitable between different students and different departments.

Dean C. M. Woodward: This discussion reminds me of one of our professors whose assistant came to him stating that he had a class in modern language and that as there was not a poor student in the class he wished to pass them all. The professor replied, "You must never do it. Condition at least twenty per cent of them. I know nothing about the class, but I am sure that percentage should not pass." You see, gentlemen, the professor had some kind of a curve in mind and the students were virtually all marked beforehand. That, in my opinion, is the danger of marking by a curve.

Professor E. R. Hedrick: In answer to a suggestion that there might be difficulties in carrying out a scheme of so mechanical a nature, I would say that no practical difficulties have arisen at the University of Missouri, except in the case of a few men who have interpreted the rule at times very

literally, and have read into it specifications that it does not contain. Thus I know of one case in which an instructor informed his class that he was obliged to give some member of the class an "*F*" grade, no matter how perfectly the work of the class was done. Such an attitude is of course indefensible and is, fortunately, rare. If the rules are tempered with a certain admixture of common sense, as they usually have been, no difficulty of the nature suggested need arise. In practice, the plan works well; and the number of cases of unwise grading at least compares very favorably with our experience before the rule was adopted.

Professor Hyde: Some time after the practice of giving excess and reduced credits was adopted at the University of Missouri fear was expressed by a few teachers that the better students in arts would take advantage of their opportunities and leave the university to engage in attractive profitable employment or to do advanced work at other institutions. An investigation revealed that not a single student had been graduated in three years, and that only about 6 per cent were able to complete the requirements in seven semesters.

In engineering the greater part of the work is prescribed, from 12 to 15 hours only being elective. To these electives students may apply their excess credits if they so desire, but in general it may be said that the better students usually carry a full complement of work.

It is impossible to prevent some teachers from misinterpreting any rule or system of rules. One insisted that the system was absolutely rigid and that students might conspire to lower the quality of the work or reduce the amount of ground covered and the prescribed percentages would still have to be assigned. That the contention is absurd goes without saying. A teacher may "fail" a whole class under this system or any other system, if the circumstances warrant.

In connection with the system at Missouri a committee on statistics issues two reports as soon after the completion of each semester's work as possible. One of these is issued in confidence to teachers only showing how each teacher has

graded his students and permitting him to compare his own record with that of each of the other teachers as well as with the prescribed average.

The other report shows the standing of various groups of students, such as Under Courses (Freshmen and Sophomore, Arts), Upper (Juniors and Seniors, Arts) and Professional Courses, Total of All Courses, Men, Women, Professional Fraternities, Freshmen-Arts, Freshmen-Agriculture, Sophomore-Arts, Sophomore-Agriculture, Class Football, Varsity Football, Freshman Basketball, Varsity Basketball, Non-Athletes, Social Fraternities, Non-fraternity Men, excluding Freshmen, Social Sororities, Non-sorority Women, excluding Freshmen, Individual Fraternities, Individual Sororities, Individual Professional Fraternities.

It is believed that the publicity in both cases is very beneficial.

HYDRAULIC ENGINEERING EDUCATION.

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The Aim of Engineering Education.

All who have given much thought to the subject of education will agree with me that the purpose of education is not so much to impart knowledge as to train the student to acquire knowledge. The purpose of technical education, therefore, is not so much to impart technical knowledge to the student as to furnish the training which will enable him to understand and investigate the conditions which surround a problem, to determine the fundamental principles on which its successful solution depends, to ascertain and analyze the elements which influence or modify it, to design the structures and works needed for its successful development, and to supervise the proper construction of such structures or works and carry them to a consummation of successful and economical completion. This, in my judgment, is the essential aim of engineering education.

Requisites in an Engineer.

The engineer must have a comprehensive understanding of the elements that underlie his problem and on which its proper solution depends. He must know what and how to investigate, and how to analyze and weigh the influence of every factor involved. He must be able to see or determine the value and effect of each element in the problem, and he must know where the knowledge needed for these ends is available and how to acquire it. He must understand ways and means as affecting both construction and operation, and, so far as possible, he must have developed his judgment, sense of justice and equity, and common sense.

The Content of a Technical Course.

The amount of knowledge that can be retained in the mind at any one time is exceedingly limited, and in discussing education it must be understood that the time spent in the university course as well as the mental capacity of the student are both too limited for the acquisition of anything more than the elements of knowledge needed by the practicing engineer.

For the purpose of technical education, instruction is required in the following:

1. In the fundamental principles of those sciences on which the practice of the engineer necessarily depends.

2. In those methods and calculations which must be applied in such practice.

3. There should be included to as great a degree as possible instruction in those human elements that concern the personal relationship of the engineer with his fellows, with his clients, with contractors, and with the public, and also those matters of judgment, equity and ethics upon which the highest success of the engineer depends no less than upon his technical knowledge.

Judgment.

Judgment can be developed by experience only, but the tendency of technical education is rather to the detriment of judgment. If text-books and instructors are considered infallible, if their lectures and dicta are to be taken without question, the development of judgment is certainly not stimulated. An earnest effort should be made to point out the limits of theory and the point where judgment and speculation begin. The use and abuse of formulas should be noted, and their limitations pointed out and emphasized. Every experienced engineer recognizes the convenience of formulas but also understands the danger of their careless application. I know no better way of encouraging judgment or emphasizing the limitations of formulas than by a careful and detailed study of actual professional problems where the uncertainties are clearly pointed out. I have had a great many young men

in my employ in private practice and have found that in a great many cases they were largely dependent upon formulas with which they had become familiar in their college course, often assuming them to be absolutely dependable when frequently they were not applicable to the particular cases at hand. Again, in many cases, if the formulas were not available, the work at hand was attacked with great difficulty.

Ethical Principles.

One of the most important factors of technical education in every line is the ethical attitude which is necessary for engineering success. This can not well be taken up as a special study, but should be introduced by instructors whenever the time seems appropriate.

Most practicing engineers recognize the fact that a true view of ethical relations is fully as important as technical knowledge, and no student should leave his university without being impressed with the more important ethical principles. One of the most important of these is a knowledge of self-limitation, and an appreciation of the fact that success is mainly due to hard work and not to great brilliancy. The student must be brought to appreciate his own limitations and the meagerness of his knowledge, and must learn that success in any line is dependent on thorough, hard, conscientious and intelligent work. Most so-called men of genius have accomplished results by constant and unremitting application, by untiring drudgery, rather than by great brilliancy; and all that is most worth while in life is accomplished or secured in the same manner. Opportunity is undoubtedly important, but hard work usually creates opportunity, and no man accomplishes true success without these elements ingrained in his character.

Another characteristic of success is dependability. No amount of knowledge or work can take the place of this attribute. The man who can be depended upon is ever in demand and if he has also acquired a high degree of technical training and an appetite for hard work, his success, barring accidents, is assured.

The teaching of such principles is difficult but essential, and should be introduced in the technical course with professional subjects. It can, I believe, come best from those instructors of more mature years who are most closely in touch with practice.

While the average student objects to "preaching," I find that no other subjects so intensely interest a class of advanced students as those which have to do with the relationship of the engineer to life and to the ethics of professional practice.

Breadth of Education Desirable.

All knowledge is more or less related, and every subject bears more or less directly on every other subject. It has been said that if any man knows all that can be known of any one subject he knows all that there is to be known of every other subject. Such a comprehensive knowledge is of course ideal and impossible of realization, but a broad foundation of many subjects is necessary to a true appreciation of any one. This is especially true of technical knowledge; and for a broad knowledge of any specialty it is both desirable and necessary that the student have a general knowledge at least of other specialties.

Danger of Extreme Specialization.

There is, perhaps, no more narrow man than the specialist who knows nothing of aught but his specialty; he is an unsafe guide except along his own narrow lines, for when his lines cross or run parallel with other subjects, he has no true perspective of relative importance or of relative values.

It has been said that if you are sick and go to a tailor, his prescription will be a new suit of clothes. Every thoughtful engineer will realize that his personal experience and bias will influence his recommendation. Recently a proposition was under consideration that involved the installation of two pumping engines of six million gallons capacity in a location where it was undesirable to construct a boiler plant and where in conseqence power had to be transmitted in one form or

another for about a quarter of a mile. Various electrical engineers who were brought into the discussion uniformly recommended the use of electrical generation and transmission. A large steam-electric installation was already available in the main plant, and the electrical engineers advised the use of that plant which, however, was about four times too large. When it was pointed out that the efficiency would be very low on account of the large size of the generating plant, the electrical engineers advised the installation of a steam-electric plant of proper size for the work to be done. After due consideration of the proposition, steam transmission, the steam pipes being carefully insulated, was installed. The steam consumption of the plant actually installed was about half of what it would have been with a special electrical plant designed for the service, and about one-quarter of what it would have been with the large plant that was already installed; and at half and quarter loads, at which points the plant operated a considerable portion of the time, the saving was very much greater. The error in the advice of the electrical engineers is therefore obvious. The tendency of the specialist is always to advise the application of his specialty.

I believe that one of the most important elements in the instruction of the young engineer is to lead him to appreciate not only his own specialty but to give him a correct appreciation of the specialties of others. The engineer who is educated in only one specialty and has not the knowledge necessary to compare it with others, is poorly prepared for professional life, and his training will not give the best results to either himself or his clients.

Specialization is, in my opinion, a serious mistake if carried far in a university course if the desire is to educate engineers instead of training skilled workmen. The ideal university for the education of the engineer is not a trade school. The education should be largely general, and special branches should be so handled as to broaden and not to narrow the student; they should be considered with relation to other lines with which they may have to be compared.

Engineering Courses Fairly Satisfactory.

In most branches of engineering, the courses of our engineering schools are fairly satisfactory. The principles and methods on which investigations and practice must rest are fairly well covered, and the young engineer when he leaves his technical school is fairly well prepared to undertake the minor calculations and designs in the practice of his profession. He still needs experience, postgraduate study and investigation, which are necessary for more advanced work and can be obtained to the best advantage concomitant with the practice of his profession.

The Weakness in Hydraulic Engineering Education.

In the teaching of hydraulic engineering there is a decided weakness in the professional courses pursued in most schools. The great loss of life and property in recent floods; the similar losses caused by the failures of dams and reservoirs within recent year, and the errors in estimating hydraulic resources, resulting in the partial or complete financial failure of many hydraulic projects in irrigation, water power and water supply, point to the great need of fundamental education along hydrological lines both of the people as a whole and of engineers on whose shoulders more particularly rests the responsibility for the success of these various projects.

Since the recent disastrous floods, the lack of exact information has become especially apparent. A great deal of so-called knowledge concerning hydraulic and hydrological matters is simply speculation, or may even be classed as fable and superstition, which even a little investigation would show to be erroneous. As examples of these errors into which both business men and engineers are frequently involved, numerous instances might be cited. Mr. James J. Hill, in an article in one of the recent magazines, points out that the building of levees along the Mississippi River is a failure because the river is gradually building up its bed almost as fast as the levees are constructed. Now it is a fact which has been demonstrated by some 400,000 soundings by the Mississippi River Com-

mission, that the Mississippi River is not building up its bed, and the proposition laid down as an axiom by Mr. Hill is entirely in error. Another popular fallacy is the universal adaptability of reservoirs to prevent floods, that reservoirs furnish the solution of flood prevention. In a recent paper by Colonel Townsend, president of the Mississippi River Commission, delivered at the Drainage Congress in St. Louis, he made the following statement, which can be readily verified. Taking into account the length of time in which the water would reach Cairo from Pittsburgh, St. Paul and St. Joseph, even if at that time reservoirs had been available with capacity sufficient to have cut off the flow of the Mississippi above St. Paul, of the Monongahela and the Allegheny above Pittsburgh and of the Missouri above St. Joseph, the height of the water at Cairo would have been reduced but six inches. I know of no better illustration of the limitations of reservoirs as a universal panacea for floods.

Not long ago I received a letter from the editor of an engineering magazine calling attention to the control of the Chagres River by the Gatun Dam, saying he hoped that all engineers would unite in the recommendation to apply this same principle to the control of the Mississippi River. Could any proposition be more absurd? Even a layman should realize that physical conditions must control, and that no scheme of flood control is universally or even generally adaptable.

The popular clamor for waterways as a sure cure for commercial and transportation difficulties, regardless of detailed consideration and investigation, and the theory of the universal influence of forests in conserving, equalizing and improving the flow of streams, are examples of erroneous hydrological ideas that will not bear the test of careful and thoughtful investigation. These subjects should be so considered and discussed in a hydraulic engineering course that the future hydraulic engineer will realize the necessity for careful investigation and the determination of the actual value and influence of a given structure or plan of development on the

betterments desired, and not be misled by popular clamor and irrational assumptions.

Necessity for Hydrological Education.

Experience in the field has demonstrated the fact that more failures have resulted in various projects of hydraulic engineering from a lack of an adequate conception, on the part of the designing engineer, of the fundamental principles of hydrology and of the importance of hydrological factors, than from defects in the design or construction of the various structures involved. In many cases the engineer has not possessed sufficient knowledge to appreciate the necessity for hydrological investigation and study, and very frequently has ignorantly made unwarranted assumptions and neglected any investigation whatsoever, because of the lack of such appreciation.

As a result of this lack of appreciation of the fundamental basis on which every sound hydraulic project must rest, we find numerous irrigation projects completed at large expense but without adequate water supply; water power plants constructed on streams not having sufficient available flow, or with such irregular flows as to make the projects entire or practical failures; spillways and gates in dams constructed with inadequate capacities for the passage of extreme floods; pumping stations constructed to utilize supplies of water which are too limited for the purposes for which they were intended, or with supplies polluted, or otherwise undesirable; communities and industries located in situations where they are subject to serious overflow and unnecessary flood damage; protecting works built with no adequate idea of the maximum necessities of the case, or their effect on flood heights; drainage enterprises undertaken with no adequate knowledge of the flood capacities which must necessarily be provided for extreme conditions. In many ways unnecessary losses are frequently entailed which have been due largely to the fact that the attention of hydraulic engineers has not been called to the importance of hydrological information, the sources from

which such information can be obtained, or the necessity and methods of undertaking hydrological investigation and study.

Necessary Limitations of Technical Instruction.

The subjects considered essential in technical education are so numerous that it is very evident that scarcely more than the barest outline of any technical subject can be acquired within the necessary limits of a university course. It is, of course, manifest that in the brief time available for professional studies in technical schools the lines of instruction must be more or less limited, and that a full consideration of any professional subject must be left for the investigation and study of the young engineer after he has begun actual practice of his profession. No professional study can be attempted except in a most elementary and incomplete manner; but in every case the student should receive instructions as to what to study, and how to investigate in his own special line of professional practice.

For example, the subject of water supply, which is treated in one semester in most universities, usually occupies the time of the student about one hundred and fifty hours, or the equivalent of fifteen or twenty days. During this limited time, instruction must be given in the entire subject of water supply, including the sources of supply, development of underground and surface waters, distribution systems, standpipes, reservoirs, pumping machinery, and numerous other subjects. Any practicing engineer will spend usually more time than can be given to this entire subject on a single phase of a single proposition which may come before him. It is therefore obvious that such a course can cover only briefly the most important points, and that the student when he leaves his university knows nothing about the comprehensive subject of water supplies except how to investigate and study the subject. To instruct the student in methods of investigation and study is the only attempt that can reasonably be made in the teaching of any professional subject such as water supply, water power, irrigation, drainage, etc. This is the object of such a university course.

THE CONFIRMATION OF TECHNICAL INSTRUCTION.

Technical knowledge to be of the greatest value must be confirmed by practice. Even the fundamental principles acquired by the student become truly his only after they have been demonstrated under many conditions and in many places. When the statement of the teacher and of the text has been fully investigated and verified, then and only then is the knowledge truly acquired. It must, therefore, be understood that university work to be of real value must be supplemented by study, observation, practice and experience.

The deficiencies in hydrological training are well illustrated by the following example. I had occasion only a few years ago to examine an irrigation project in the arid west that had been laid out by a graduate of one of our engineering institutions. The design, so far as the structural features were concerned, seemed to be excellent. When the question of water supply was discussed, the engineer in charge stated, "Oh, there is plenty of water, there is no question about that; I have been around that stream for several months, and I know there is always plenty of water." Later, when the matter was examined in detail, it was found that there was not over one third to one fifth of the water that would be required, and the engineer finally remarked, "Well, to be honest, I did not know how to make an estimate of the water supply or how to investigate it."

On this same project, an older and more experienced practicing engineer, who was in charge of a similar project costing over three million dollars, visited the same work, and a rainstorm occurred at the time so heavy that the gullies were running full and he had to wait several hours before making some small creek crossings. From his chance experience, under most unusual conditions, he said, "Gentlemen, you have water enough to irrigate this whole valley." An investigation of the water supply showed so little water that the project was rejected as impracticable.

I have seen so many errors of this kind in my examination of projects in the various lines of hydraulic engineering that

I believe engineering schools should give some attention to this subject. I do not wish to imply that a great amount of time is necessary, but rather to express a belief that the attention of the student should be drawn to these important hydrological subjects and that some systematic course of limited extent should be arranged to point out the dangers in hydraulic projects of ill-advised plans based on inadequate knowledge. The source and necessity of such knowledge should be made plain to the student, so that when the time comes he will know what his problem is and how to study it.

The teacher cannot expect to impart to the student the knowledge that can be assimilated only by long years of experience. Even the engineer in practice can keep in mind only those things with which he is in daily contact: he must look the others up; he must study them; he must acquire and reacquire them as he needs them.

Educational ideals are by no means fixed; they must grow and develop; they must change with the times and the circumstances. In my judgment, most engineering courses can be greatly improved by a judicious introduction of the personal and ethical factors. In hydraulic engineering courses much more attention should be given to fundamental principles which have in general been too long neglected.

The ordinary engineering course provides fairly complete instruction in mathematics, strength of materials, design of structures, and in the calculation of problems connected with those physical phenomena on which the practical success of engineering structures must depend. The whole training of the engineer emphasizes the necessity of a knowledge of the principles of design in order to give adequate strength and stability to the structures to be designed and installed. While errors in such designs are only too abundant, they are, in hydraulic-engineering projects, much more limited than the more fundamental errors that are due purely to the lack of appreciation of the very element of the problem on which success most depends.

No engineer would attempt to design the physical structures

of a water-works system or water-power plant without endeavoring to acquaint himself with the principles and practices on which the successful construction of such structures must depend; and yet, the water supplies on which the success of these projects is entirely dependent are frequently only superficially investigated, or the sufficiency of supply assumed. It would, therefore, seem illogical that our schools should provide instruction in these technical subjects which can readily be taken up by the engineer in post-graduate study, either in college or out, and fail to provide a thorough course in the fundamental underlying principles of hydrology on which the success of all such projects *must* largely depend.

A certain amount of professional study in a technical school is undoubtedly desirable inasmuch as such study permits instruction in the methods of investigation and design, and points out the application of the previous theoretical work of the student. It seems illogical, however, that such professional study should be pursued to an extent which will cause the neglect of a line of instruction so important to the ultimate success of the hydraulic engineer.

Hydrology.

Hydrology should treat of the laws of the existence and distribution of water over the earth's surface and within the geological strata, and of its sanitary, agricultural and commercial relation. It should discuss hydro-meteorology principally in relation to the occurrence, distribution, variation and disposal of rainfall and the run-off resulting therefrom, in drought and in flood. It should discuss the modifications of the run-off caused by evaporation, topography, geology, temperature, and various other factors, and the variation in run-off as the factors vary in importance. The great variations in the unit run-off under similar rainfall conditions but different physical conditions, and under similar physical conditions but different rainfall conditions, should be studied, and the marked differences which arise in different parts of the

country depending on these differences in conditions should be discussed and appreciated. The effects of storage, of cultivation, of forestation, and of other artificial physical modifications of the drainage area on the flow of streams should also be discussed.

The study should include hydro-geology, or the occurrence of water in the strata, and the laws of its occurrence and flow. This must presuppose or include a sufficient study of general geology to give a comprehension of the geographical limitations which must be expected in hydrographic conditions, and the modifications due to geological changes. Water as a geological agent should be discussed, and through such discussion and study a comprehension of the birth, the growth, and the development of drainage systems and of rivers attained. The apparent lawless and erratic action of streams will be thus found to follow laws more or less distinct and which must be studied and comprehended before intelligent river conservation becomes possible.

The rainfall and other accompanying phenomena are proverbially inconsistent; and yet the study of hydrology shows that there are limitations to such inconsistencies, which limitations are quite as narrow and exact as those that arise in other engineering fields which must be cared for by the "factor of safety," which is simply a "factor of inconsistency" in the qualities or occurrences of conditions with which the engineer always has to deal.

In the studies of water supply and storage which are offered in most engineering schools, various hydrological subjects are briefly discussed. In the study of geology and meteorology, which studies are sometimes included in the engineering courses, some of these subjects are also treated. Too often, however, mere facts and figures are presented concerning various phenomena, but such facts and figures are seldom correlated and the attempt is seldom made to establish relationships from which conclusions can be drawn and on the intelligent use of which the success of hydraulic work must depend.

In no work on the subject of irrigation, with which I am familiar, is the relation of rainfall to run-off, or the value and limitations of comparative hydrography, discussed even in a limited way, nor is any method of investigation pointed out.

In very few instances is the subject of hydrology systematically taught in a manner sufficiently complete to afford a reasonable basis for the investigation and study necessary to the successful practice of the hydraulic engineer, or even to a sufficient extent to give the engineer a reasonable appreciation of the importance and necessity of such study and investigation. In many cases the student enters professional life with no appreciation of this subject, and with no knowledge of the availability of the great fund of hydrological information which has been accumulated at the expense of much time and labor, and as a result of the success and the failure of many hydraulic projects. Surely our engineering schools should add this important subject of hydrology to their curricula.

UNDERGRADUATE TRAINING FOR HYDRAULIC ENGINEERS.

BY O. L. WALLER,

Professor of Hydraulics and Irrigation, State College of Washington.

It is the intention in this paper to discuss the advantages to be obtained from close coöperation of the engineering departments of the colleges and universities with irrigation companies, power and construction companies, municipalities, and similar organizations.

FIELD WORK.

I recommend that educational institutions give academic credit for some of the field work done by undergraduates employed in engineering work during the summer vacations and at other times; and suggest that it would be a good plan in many instances to advise the student at the close of his sophomore year to enter some engineering office at a moderate compensation for the purpose of studying its organization, getting acquainted with the way of doing things, and learning to associate with men and things. I readily see that the granting of this academic credit could be carried to an extreme, but with proper handling the scheme could be worked out to the great benefit of the student and to the profit of those employing his labor.

HYDRAULIC ENGINEEER'S EDUCATION.

I wish to discuss the question of the hydraulic engineer's education from the standpoint of what education he should have, and how he should acquire it. In the early history of engineering, his education came almost entirely from practice; later, as a branch of physics, it became generally theoretical;

then laboratory methods were introduced, and he was taught exact calibration, he performed some experiments and tests, but his teachers almost entirely failed to cultivate his judgment in dealing with problems under field conditions.

I wish particularly to discuss how the student shall acquire his information; whether his knowledge shall be gained entirely from text-books, lectures, and laboratories, or whether his judgment shall be trained in the field. If judgment in dealing with nature's problems is important, it is a necessary part of his education, before he can become a useful member of society. The question then arises, should not the student be given some collegiate credit for the work done while he is acquiring this practical side of his education; or, in other words, while he acquires that side of his education which makes his theoretical training effective.

Weaknesses In Undergraduate Work.

From first to last we have been asking the employers of engineers to tell us what they would have us teach the boys in college, but after they have told us we find it impossible to turn out the product they most want. Much has been said and written of the failure of engineering graduates to measure up to the standard set by employers. It has been said that they are not careful and exact in figures; that their results cannot be relied upon; that they are not willing to begin at the bottom and work up, believing that they have passed the apprenticeship stage. I have not observed that the same criticisms are lodged against technical graduates in fields of work other than engineering. Many reasons for these shortcomings have been advanced, some critics going so far as to brand the whole system of engineering college training as a failure. Some charge the trouble to the inexperience of the faculty, to a lack of knowledge on their part as to what employers and the general practice demand, to the fact that they do not keep in touch with the up-to-date methods and current practice in the profession of engineering. Others

find all of the trouble in modern college life; too much athletics, too much society, too much fraternity and club life, too much time lost. They allege a wrong standard of habits, expensive habits, wines, tobacco, carousing, the undertaking of many things and the successful completion of few. They allege snobbery and even training in snobbishness preventing the engineering graduate from working on a level with the more humble laborers with whom he is thrown in contact, frequently as a directing head.

It may be asked what effect did removing the boy from home and restraints of good parents during the formative period of his life have on his habits? Has the college supplied the needed counsel, restraint, and balance of his activities, or has it permitted him to behave like an engine without balance wheel, or load, and with the throttle wide open? While these points are vital I do not have the time to enter upon their discussion. They have been elaborated by other men and their observations are worthy of serious consideration. I wish to confine the discussion entirely to the student's usefulness to his employer. How shall he acquire engineering judgment and administrative ability? When and where is he to learn the method of attacking field problems, and of solving them?

Methods in Engineering Education.

Under the old apprenticeship method, a boy's entire instruction came from practice. With the abolition of that system, the major part of his information came from theory. The pendulum then swung to the laboratory which, under ideal conditions, supplies the necessary training in calibration, testing, etc. But there is a demand for knowledge that cannot be gotten from any of these sources. It must come from actual contact with the business of engineering. Only in the field where nature's conditions are met and must be dealt with, can the student acquire the judgment necessary to make his theoretical training effective, and this is better done after he has a foundation in theory. In college he learns to deal with

men, and how to get on with those of his own rank, but he does not acquire skill as a directing, organizing head; nor does he learn how to meet and solve nature's problems with any large assurance of success.

In an irrigated country with its thousands of laterals, sub-laterals, control gages, weirs, and other measuring devices, when and where shall the student learn how to locate such laterals and head-gates and to set such modules so as to secure satisfactory results? Only in the field, with overalls on, directing and actually doing the work for himself. He may have calibrated a weir in the laboratory, determined the efficiency of a pump, or measured the velocity of water in pipes, but when he goes out to run a test on a water system, he is required to adapt these laboratory methods to the conditions that obtain locally, and this power to apply is a large factor in his success. I could give very many concrete examples of the lack of judgment of young engineers in applying foundation theory to real construction. I once examined miles of flume designed and placed by a young graduate and found it entirely incapable of carrying the quantity of water intended to be conveyed. The grade was right, the section was right, the construction was good, but the engineer had used theoretical values for '*n*' in Kutter's formula without considering the effect of alignment or the effect of earth, sand, and other debris accumulated on the bottom and sides of the flume. The water works and the sewer systems of many of our smaller towns are designed by young graduates shortly after leaving college. Not infrequently we find a 4-in. fire hydrant on the end of a 1½-in. water pipe; drilled wells high up on some hill; and sewer systems with no provision for flushing.

Contact with real engineering and with the broad-gauged men executing such work would help the student to find himself professionally. Such an introduction to the real work of the profession would test his staying qualities and help him to find out whether he was suited to the profession or not. Possibly a goodly number would find other lines of work more to

their liking and would drop out of the profession; but this would be a gain, not only to the students but to the profession of engineering. At present the student graduates full of theory, some of it not well understood and much of it not assimilated by experience; and we send him out to gather engineering judgment, to revamp many of his habits and, in general, to get acquainted with his profession as best he can. True, we have tutored him in the fundamentals of his profession but he has small experience in the application of these fundamentals. If some of that practice could be gotten before the senior year, so that his instructors might assist him in adapting and assimilating his experiences, thereby helping him to eliminate rubbish, and to organize and correlate theory and practice, he would leave college very much better equipped to enter successfully upon his professional work.

The inefficiency of many college graduates is traceable to a want of judgment in dealing with conditions fixed by nature. A method of meeting and solving hydraulic problems cannot be successfully taught the student who has no field experience. It is not likely that the young hydraulic engineer will be able to control large heads of water under difficult conditions until he has had experience in harnessing smaller heads under less exacting conditions. He would not be expected to dam the great Columbia before he had acquired experience and judgment in controlling lesser streams.

Field experience in hydraulics makes for greater student efficiency. For example, in the study of embankments and earth fills, he at once recognizes the need of bond plowing and sees the necessity for exceeding the theoretical section for such embankments. Possibly he has been a ditch rider on a dry fill and knows the treachery of such embankments. He may have observed, measured and studied the seepage losses from canals constructed in the dust or through broken lava. He may have observed the excessive penetration, the waste of irrigation water near the head ditches. He may have been called into action to stop a break in the levee, to protect and save an endangered structure from a rising flood, or to meet

emergencies under other conditions, all of which experiences add to his useful knowledge, cultivate his engineering judgment, sharpen his wits, and strengthen his initiative. The two qualities, theory and engineering judgment, seldom, if ever, are acquired together, and it may be discouraging to the young engineer to leave college with only the theory, particularly if more than that is expected of him by his employers.

A young engineer, a brainy fellow, a graduate from college with high honor, accepted employment with an irrigation company, and for his first job was sent out to run a line for a lateral which should carry water somewhere from a main canal to a group of small farms some two and a half miles away. A simple enough job it was, but where should the lateral be located? what kind of control works should be installed? how much water should the ditch carry? what would be the probable percolation losses? what grade could be secured? what action should it have? what velocity would the sandy loam through which it was to run stand? how were the two interposing ravines to be crossed, and how were their flood waters to be taken care of? were some of the questions that confronted him. Part of them were easily answered from his school training, but the others presented difficulties that could be answered only from systematic observation, and experience in the field.

It is what the engineer knows that is useful to his employer, and he never knows a principle thoroughly until he has worked it out in practice. So far as it goes the laboratory does this, but it does not cover the great outside laboratory of construction and operation.

College Credit Based on Field Experience.

Can a college allow credit to apply on a bachelor's degree for work done by the student in this greater laboratory during vacations or term time? And if so what credit should be allowed and what shall the credit stand for?

At the State College of Washington many of our engineers

are self-sustaining, have been employed on engineering work before entering college, and seek such employment during their vacations. This has given them a view-point that materially aids them in attacking problems in the class-room. They readily grasp the application of the theory to engineering practice and to field problems. We give credit on the college books for such work. Such credit is not a function of the time spent, but of the net experience gained, and the grade awarded is not permitted to stand for the theory that goes with such practice. The theory may afterward be acquired from lectures, or text-books, and is to be used as the digestive fluid by which experience is assimilated. There are some difficulties in finding out how close an observer the student has been of the engineering work upon which he has been employed, how much he has assimilated, and of his adaptability to work with men and things. This information could probably be secured in two ways: partly by examination, and partly by a series of interrogatories addressed to his employers, and to the engineer under whose direction he worked.

Attitude of Practicing Engineers.

In discussing this subject of the sources from which the engineer should acquire his working knowledge with some of the leading engineers and city officials of the northwest, I find that they all heartily commend the plan outlined and express willingness to assist in carrying it out. If the student accepts employment for its educational value, the agreement with his employer should be conditioned on his being advanced or transferred through all stages of the work, even to the organization and administration end of it.

The field experience discussed in this paper will probably not result in developing the student into a full-fledged engineer. Experience, however, has shown that he is a better and more comprehensive student, that his conclusions are more rational and that he is the first man to find remunerative compensation upon leaving college.

Discussion of Hydraulic Engineering Education.

Mr. J. W. Ledoux:* In the matter of education, if we look at the subject broadly, it is believed that all engineers will, upon reflection, agree that the ultimate purpose should be the intrinsic and material advancement of society because society is permanent while the individual is ephemeral; in other words, the education of the youth as well as the man in the practice of his profession should be such that when he finally finishes his work in this life, his influence will have been a permanent benefit to society, and that he has left it on a higher plane than when he entered. Therefore, in considering any particular phase of education, the first question should be, does it fulfil these fundamental requirements? In most discussions on this subject other purposes are generally given. For instance, that education is considered best which enables the man to make a better living, to possess an unequal advantage over his fellow man, to become a better mixer, to have more culture and refinement, to be more peaceable and to have more facts and information at command. None of these things fulfils the axiomatic object above given.

The inventor of a process for performing a given amount of useful work with less labor, even if he be unsophisticated, uncultivated and unrefined, has performed more real service than one who possesses a fund of popular information and is generally recognized as a good fellow in society. The knowledge of history and foreign languages and social usages is of absolutely no value unless it tends to the ultimate advancement of society.

The trouble with a good deal of education is that some of the most important matters are entirely neglected, and those which are not are taught with insufficient thoroughness to become of practical value. It seems too bad, with all our advancement in the sciences and arts, that our recognized public methods of education have not kept pace with the advance of science, and in the writer's opinion, there is no treatise on

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education and practice in this line that is equal to that recommended by Mr. Herbert Spencer as far back as 1860. The schools and colleges of today would make an immense advance if they followed out his scheme *verbatim*.

The education of the young man may be likened to the tools of a workman; there are very many poor workmen who have good sets of tools, and there are also many men of fine educational training who cannot apply it to any practical use. The two purposes should be combined in the schools and colleges, viz., the furnishing of the tools and their application. What is the use of giving a man three or four years of training in a foreign language when this training is not sufficiently thorough to enable him to use it practically? How many men are there who have obtained a mathematical diploma in academies and colleges, who are not able to determine the fifth root of a decimal by logarithms, or work out the simplest practical problem in calculus? This kind of a training is worse than nothing because while spending the time over it other things of value are being missed.

As to the curriculum, I think the essentials are, first, the English language, because its acquisition enables one to study other desirable things; second, mathematics, without which we are not able to go very far in the sciences; third, the natural laws, and one of the most important of these is the law of gravitation, which is the basis of all mechanics. These laws, which are eternal and immutable, are so multitudinous that it is impossible for any individual to become expert in more than two or three, but their study constitutes the greatest education.

Our schools take up too much time with the study of phenomena instead of the laws or principles upon which these phenomena depend. As an instance, the study of history is of no value except in providing an understanding of sociology, or the laws of society. The laws of electricity, heat, light, biology and chemistry constitute in each a life study.

To go very far in his profession, it is necessary for an engineer to be thorough, and therefore to specialize in some par-

ticular branch. On account of the present constitution of society, a young man is very seriously handicapped in his choice of an occupation in which he could be of the greatest benefit to society, the paramount practical consideration being to select that pursuit which will enable him most certainly to make a living for himself. Therefore, the world loses the benefit of the fine qualities that exist in many young men in lines in which they are better fitted to follow, but they are deterred on account of the fierce competition of the commercial world. Frequently a man who should have been a miner or a farmer is a vendor of groceries, and the man best adapted for engineering is engaged in the base-ball or advertising business, because it pays better.

Coming down to the concrete, the writer is of the opinion that the best training for the hydraulic engineer consists in English, arithmetic, the elements of algebra including logarithms, plane geometry, plane trigonometry, a practical working knowledge of elementary general geometry and calculus, descriptive geometry, elementary physics, elementary mechanics and hydraulics, the use of the engineer's compass, transit, level and plane table, elements of lithology, mineralogy and geology, the elements of choice, chance and probabilities, physical geography and meteorology, mechanics of materials, resolution of forces, graphical statics, stresses in framed structures, free-hand drawing, mechanical drawing, the properties of steam, the principles of prime movers, the use of the indicator, and the use of the slide rule throughout the course.

All of these subjects should be taught with thoroughness, and the only way to do this is to have abundant practical examples and problems for solution. The subjects of lithology, mineralogy, and geology, each constitute a life's work and therefore it is not expected that the student can do any more than be grounded in the fundamental principles. For instance, the expert specialist in geology is familiar with all the known signs of the rocks, such as lithological, mineralogical, chemical and paleontological, and even then, can be necessarily

a specialist in only certain phases, such as iron ore or coal formations. But in the curriculum above given it is only intended to cover the general sequence of the formation of the earth's crust and the ability to recognize these formations from their general appearance. To do this it is necessary to have a good understanding of lithology, and to understand lithology well, it is necessary to know mineralogy.

In the writer's opinion, it is of great advantage for the student of hydraulic engineering to have actual practice either during or before the course, and for this purpose the correspondence school or the night school is believed to have, in some respects, an advantage over the college course, because it can be carried on simultaneously with practical work.

Nothing has been said concerning the training of moral character, the study of hygiene or sanitation, artistic development or culture, but all of these matters are left to the individual.

While the above is a material abridgment of the prevailing course in technical schools it is a formidable array of essential subjects in hydraulic engineering, but there are many other subjects omitted which a great many engineers would include in the curriculum, such as for instance, chemistry, metallurgy, thermo-dynamics, electricity, dynamos and motors, kinematics, machine design, foundry and machine-shop practice, electro-chemistry, bacteriology, botany, scientific management, accounting, shorthand writing, French, German, Spanish, Latin and Greek, stereotomy, building construction, foundations, masonry, roads, streets and pavements, landscape gardening, roofs and bridges, reinforced concrete, jurisprudence including the laws of business, contracts and specifications, political economy and literature.

But, even after a thorough preparation of the subjects above recommended, the education is only begun, and by the earnest engineer, is pursued in after years with practical experience in his own particular line of work.

John C. Trautwine, Jr.:* To a young man, entering what is

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called "political" practice, a veteran "politician" gave this advice: "Find out which way the procession is going, and get in front"; and, whatever technical training and knowledge "the young hydraulic engineer" may have on entering hydraulic engineering practice, it will do him no harm to look about him, and (before getting in front) see which way the procession is going.

A paper, presented to the Western Society of Engineers by Dr. C. P. Steinmetz on October 25, 1912, and printed in that society's *Journal* for March, 1913, throws valuable light upon this subject.

Dr. Steinmetz's paper is entitled "Future Problems of Electrical Engineering"; but the problems suggested by him are present problems; and, although illustrated by electrical practice, they are industrial and social, rather than electrical.

Dr. Steinmetz might, therefore, have omitted from his title the words, "future" and "electrical," and might have called his paper simply "Problems of Engineering." His illustration, drawn from the field of electrical engineering, must appeal strongly to the young hydraulic engineer; for, in these days of water-power development, whatever affects electrical engineering must also affect hydraulic, though perhaps not water-supply, engineering.

Dr. Steinmetz's paper points out the route of the procession, and he brings his lesson more closely home by means of diagrams, intended to illustrate the several stages at which electrical engineering has successively arrived, and that which it must next reach.

These stages, four in number, arranged chronologically, and illustrated, respectively, by my figures 1 to 4, are briefly as follows:

1. In the beginning it was the fashion for manufacturers, using electrical power, to install each his own little electric generating plant, producing for himself the current required for his own purposes.

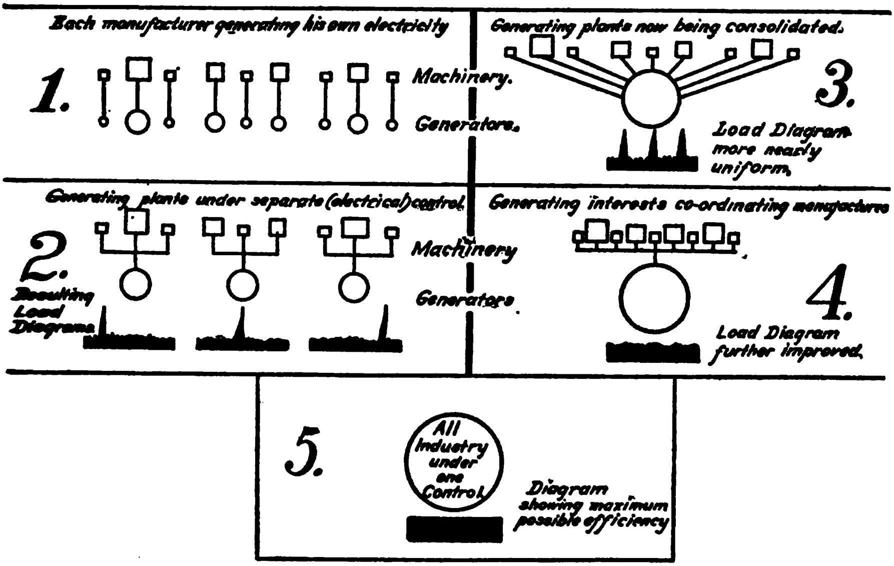
2. But the generation of electricity soon gravitated away from the hands of the manufacturer of other utilities, and

into the hands of men who confined themselves to it; for it was found that, by thus specializing, they could employ and coördinate the services of higher class engineering talent, and, by generating electricity upon a larger scale, could of course produce it more economically.

3. And separate plants, for the generation of electricity, are now gravitating from separate to combined control; bringing, of course, their clientages also under that one con-

EVOLUTION OF ELECTRICAL INDUSTRY

See Dr C.P. Steinmetz, Journal of the Western Society of Engineers March 1913.



trol, so far as their supply of electricity is concerned; for it is found that single generating plants, of moderate size, and each serving only a few manufacturing plants, as in Fig. 2, are at a disadvantage because of their low "load factors," each of the few manufacturing customers of one generating plant having his daily and seasonal peak loads, and thus requiring a large supply of current during a short time; while, during the rest of the time, he requires but little. With but few

such customers, the generating plant, which must be of a capacity capable of meeting the *maximum* demand, must lie idle or only partly employed during much of the time. This is obviated, as in Fig. 3, by combining a number of separate generating plants into a single large system, thereby combining also their areas of service, and increasing the diversity factor and the load factor.

For instance, Dr. Steinmetz mentions that electric trunk lines, "radiating from Niagara Falls, say, to Erie on one side, and to Syracuse on the other, meet a variation of one hour in time; so that, if you would supply all the energy of Erie and all the energy of Syracuse, and even if those cities had identically the same load curve, you would get a diversity factor due to the time difference," and of course a higher efficiency.

4. According to Dr. Steinmetz, the next step will be for the large concerns, generating electricity, to reach out and study, and in some way control, the electrical requirements of the manufacturing industries which they serve, in order better and more economically to adjust the demand to the supply.

5. But, we may now ask, "What then?" Does this not lead logically to a combination of all the industries, including that of the generation of electricity, under one great directing and controlling force, with resulting economies, at present hardly dreamed of? If so, it is inevitable.

Bellamy foresaw just this, happening at just about this time; but he saw his vision a quarter-century ago; and it is perhaps not strange that, with the limited facilities then afforded, he could conceive of all this as going on, under exclusive and absolute private control, such as then obtained, until, some fine morning, the nation should wake up and take the management into its own hands, presumably allowing the former magnates to remain in charge at liberal salaries; whereas we of today see the process of absorption of industries going on simultaneously with their growth.

A little observation must satisfy the young engineer that we have reached that stage of industrial and social develop-

ment where the dominant feature is the subordination of the individual to the community, the absorption of the small plant by the "trust," and that the tendency of things today is irresistibly toward the elimination of private, in favor of public, ownership and operation of all industries, as we have long had it in our municipally owned and operated water-supply systems.

Thus, referring to coming "changes in our industrial and in our political condition," Dr. Steinmetz well says:

"Obviously, when electric power generation, transformation and distribution are as essential for the welfare of the country as are the freight and passenger transfer and distribution by our railway systems today, then it will no longer be permissible for any farmer or any village council to stop the electric transmission lines from being installed and operated. Before the twentieth century has advanced any considerable extent, we shall have a code of laws producd in accordance with the conditions of the twentieth century, and not a mixture of laws and rulings representing decisions from the time of Alfred the Great and William the Conqueror up to the days when the New Englanders burned their witches."

The fundamental thought, suggested by Dr. Steinmetz's paper, is that the day of small things has passed, that the near future is to see nation-wide activities, and that these cannot be controlled, with satisfaction to all, by individuals or by small groups of individuals taking their remuneration in the shape of profit. Nothing short of national control of all industry can satisfy the requirements of the next generation or two.

It behooves the young engineer to recognize that we are in the midst of the rapid formation of a vast and highly organized national industrial army; as incomparably superior, in efficiency, to the still largely unorganized mob of today, as the German army is superior to a horde of unorganized savages. He will do well to shape his course accordingly.

Mr. L. J. LeConte:* The courses of instruction taught at our standard universities are theoretically all right, embracing physics, chemistry, geology, applied mechanics and mathematics, ending up with trigonometry and analytical geometry. Calculus and the higher branches of mathematics can be omitted entirely. With this as a foundation, then structural and hydraulic engineering can be taken up and carefully studied. When the young man graduates and gets his diploma, he is literally full of book knowledge, but is entirely devoid of either experience or judgment.

Good judgment, exercised in any given case, is that invaluable quality of mind born of long experience. It cannot be acquired simply by reading books, for the simple reason that, as a general rule, busy men full of valuable experience do not write books, they do not have the time or the inclination. The proper thing for the young man to do is to go into the office of a leading hydraulic engineer and there learn the practical side of his business, which is far more important to him than the mere theoretical side of his education acquired at the university.

In order to acquire this valuable knowledge he will probably be required to spend four or five years in this subordinate position; but when he comes out and opens an office of his own he feels much more confident and self-reliant and is well armed for the battle of life.

The writer cannot close this brief without one or two cautionary remarks. Let the young man study his particular case on hand carefully in every detail, and if anything is doubtful make another survey until he is sure of his facts. Then when he comes to apply the usual formulæ to his case he should remember that all formulæ are based on small-scale experiments, and they are, therefore, only applicable to a limited number of cases on nearly the same scale. When the formulæ are to be applied to big cases, they no longer fit, and the engineers are compelled to modify them accordingly.

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Professor R. L. Sackett:* In the western states the man who studies hydraulics takes up irrigation; if he go south he goes into drainage; if he take a position under the government on the Great Lakes, he is engaged in river and harbor work, or if he is in other lines of what we call hydraulic engineering in this or adjoining states, he goes into water-power engineering and hydro-electric practice.

Now manifestly the employer should not forget that the engineering graduate has been a boy for four years, and is still practically a boy. A great many employers do forget that they were once boys themselves, with the limitations of boys, and they ask too much of a college graduate. It is entirely impossible in a four-year course, particularly if it includes paleontology and the other things, for him to get very much of the specialty of irrigation engineering, or waterway improvement, or drainage, or hydro-electric practice. He must, of course, acquire the fundamental principles or backbone; but as soon as we get beyond these fundamentals and into the details of a specialty the university is getting on dangerous ground.

The student needs to understand the fundamental principles, to know them for himself outside of the dicta of the professor. As soon as one goes beyond these fundamentals in the laboratory up into the specialties, he is getting into the realm of empirical education. When we tell a young man that a horizontal wheel is the thing that he ought to use here, in hydro-electric work, and a vertical wheel somewhere else, or twin power, or quadruplex, or something else, the information is largely empirical and its tendency is to take from him his own independence and make him more or less dependent.

What we want is that technical education which gives him a firm grasp on himself and on the fundamental principles, so that he will feel as sure of his deductions as was James B. Eads when he said that, given first a simple scientific principle, the results should be infallible because when the principle

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is applied no mistake can be made. If we keep before us simple fundamental principles, we are at least building on a sure foundation and keeping our feet on the ground. With that proviso the speaker confesses he is not so much concerned about the particular line of differentiation which the young man shall follow during his four-year course. During the fourth year perhaps he may specialize somewhat; but it does not matter so much whether this takes the form of irrigation, or of hydro-electric practice, or of locks and dams and river control, so long as he is encouraged to use his individuality, his judgment, his knowledge of simple principles. The speaker says, "so far as he can," because the limitations are there and we must recognize their existence. When he gets out into the field, he can go far into the specialty which he undertakes.

We must not forget that the boy of today, when he goes into hydraulic engineering after graduation, is taking up work that calls for the exercise of rare judgment, and he has little experience upon which to ground that judgment; therefore I do not believe in too great differentiation in college.

If I properly understood Professor Mead, I agree with him in his statement that the graduate should have a knowledge of the fundamentals and the practical limitations which are imposed by the laboratory. He certainly should have been well drilled in the principles of hydraulics if he is to go into power lines, or, if he is to pursue water-power construction, he should study topography, geology, and rainfall, because they are the fundamentals for lack of which so many failures have been made in connection with hydro-electric development.

This, too, leads to another suggestion, that in addition to what is usually included in the curriculum, the student should know something about finance. Very few boys have had any contact with business. They have had no occasion to direct their thoughts to the financing of engineering undertakings nor to learn how securities are made valuable. They do not know much about depreciation. To be sure they can not learn much of these things practically; but they should know

something about methods of financing propositions so that they shall have an idea of the financial side of every project, because a man is not going to invest his money on an engineer's report unless the project shows some prospect of financial returns.

Now concerning the college boy as a worker, I am here in his defense. To be sure, he smokes cigarettes and a pipe, a good deal for show, and a good deal by imitation; and undoubtedly we shall agree that it is not to his benefit. Nevertheless, in spite of these limitations, the college graduate on an average is as hard a worker, in hours per day, and as willing a worker as you will find anywhere. All who have employed college graduates of the average quality will agree to that. For example, only a couple of weeks ago certain informotion was desired by an employer. A college graduate got it for him within a limit of time in which only a college graduate could have gotten it, and by methods which he himself originated. He began working by early daylight to gather the information necessary. The average man would not have done such a thing as that on the pay given him, ordinary commercial pay. And the graduate is just as efficient a worker as we should expect from his years and his experience; and we must not expect too much. There is still another thing to be said, namely, that the young man from college on an average, besides his energy and ability displayed where technical knowledge is desired, possesses certain other qualities of manhood which after all surpass his special technical ability.

I feel from my own experience with the college graduate that he is on the whole a very reliable fellow, although sometimes ashamed to ask for information for fear of exhibiting his ignorance; but under the circumstances he is quite as reliable on the job and quite as persistent in getting at the thing which he believes is wanted as the man who has spent four years in practical work instead of the university. He is reliable, and that certainly is one of the things that he must be. He is ambitious within reasonable limitations. He is

not very egotistical; while at the same time he has some confidence in himself gained during his college course.

If he has obtained these fundamental principles of hydraulics, and laboratory experience sufficient to show their application; if he has a knowledge of his own limitations; if he is a good, clean, reliable fellow, and serious-minded, there is not much fear, no matter what the particular specialty to which he may apply himself, but that he will show up fairly well if the employer will but remember that he was himself a boy once upon a time without the capacities of a man.

Professor C. C. Thomas: Will Professor Waller give a little better explanation as to the matter of credits given for practical work done outside of the college?

Professor Waller: One illustration which will probably help us as much as anything. A freshman came into college and was classified. Two weeks after that I met his father and had an opportunity of talking with him for an hour or two. The conversation revealed the fact that the young man had been employed in an engineering capacity for some two summers, the most of his duties being in railroad work. He had done plain surveying field work, and also field work in topography and a great deal of work in railroad location. We classified him, giving him credit for laboratory work, for field work and plain surveying and topography and such part of railroad work as he had done, and then held him accountable in the class lecture work for the theory that went with it.

Professor Wm. T. Magruder: Mr. Chairman, we engineering educators were very desirous to hear from the hydraulic engineers who are in attendance at the Water Works Convention, and feel that we have learned much tonight from those who have spoken; but we want to ask a few questions. Was it a college-bred man who put a four-inch plug on the end of a one and a half inch pipe? If so, could any human being have taught that man common sense? Is there an engineering college in the country which gives a course in common sense? Is there a professor of common sense in any engi-

neering institution in the world, including the naval and military academies of our own country? In order to train a man in common sense, you need to begin with his grandmothers, if not earlier.

We have heard a great deal about what should be in the curriculum of the engineering college, and the speaker is very thankful to Professor Sackett for what he has said. We in the teaching branch of the engineering profession find it impossible to work ourselves or our students more than twenty-four hours a day, even in emergencies; and we find it impossible to be continually adding new studies to the curricula of our engineering colleges and yet removing nothing therefrom. Curricula have "yield-points" and can "break down," like other things. We would gladly turn out a more finished product, with twenty or more years of experience to its credit, if we knew, or could be shown, how to do it in four years with the high-school graduate.

Mr. John W. Alvord:* I was very glad to hear Professor Sackett in defense of the college graduate, because it seemed to me that the discussion to which we have listened has been slightly pessimistic. The college graduate is not an experienced engineer, and most of the trouble that the public experiences with the college graduate appears to come from over-estimating the value of his education.

The human mind is a very peculiar appliance. If it can be properly likened to any simple illustration, I might say that it reminds me of a searchlight. You focus a searchlight on this object, and then on that object and if you have ever had occasion to use a searchlight, you will have noticed how easily it darts from one part of the darkened landscape to another under a restless but untrained hand. Now many people go through college and through life jerking their mental searchlights around, illuminating all sorts of subjects, without any very clearly preconceived purpose as to what they want to find out around them. Other people use their searchlights more systematically, exploring the dark places, uncovering areas

* Past-president, American Water Works Association.

step by step, and systematically investigating the great darkened environment into which they are thrust and in which they exist.

Now the greatest value of college education is that it develops in a young man facility in guiding his mental searchlight; it gives him some idea of how to lay up, step by step, those stores of knowledge which are to be useful to him.

We practicing engineers who take the product of the university are not looking for genius, we are looking for the plodders who can be thorough. We do not want great brilliancy; we want persistency, efficient, thorough persistency. We realize that the young college graduate has not much perspective or a wide horizon but we know that he has been trained to use his searchlight systematically, that, if he is given a chance, guided by wise counsel, he will make good, and become a valuable member of society.

With these reservations, it seems to me that we have excellent material in the average college graduate. Some fifteen or twenty years ago the college graduate came out rather self-sufficient, sometimes showing a tendency to instruct the boss; but that day has passed, the evil was early seen. You rarely find the college graduate coming out in that frame of mind which would make him feel that he ought to be in a few months on a high salary; he realizes his limitations. Sometimes he is even too timid, as Professor Sackett has said, in really getting his proper point of view and in really letting us know what he needs to know in order to be efficient in the new life which he enters.

I believe in the engineering college graduates. They have in some respects a slow, patient and heart-breaking job ahead of them. The introduction to any profession is a slow, patient and heart-breaking job for the young man; it is an up-hill task requiring persistent effort. The young man has got to build himself up little by little. If he build solidly, he cannot do it quickly. The public instinctively will not accept the young man's judgment until he has piled up behind him in a more or less arbitrary fashion a sufficient number of years of

experience. The public at large intuitively feel that years in a general way offer some guarantee that a man has acquired the common sense which is valuable, as well as a proper working knowledge of the physical and social laws of nature. And until that time comes the young man in any profession passes through a transitional period which seems to him very slow and very, very heart-breaking indeed sometimes. All this too comes at a critical period of his life when he wants and needs money. He perhaps desires to marry; he wants to establish himself. Yet there usually lies before him after college four, seven or even ten years, as the case may be, of slow, patient work, which is in a large sense supplementary to his college education and in addition thereto, which must be gone through with patiently and persistently, if he win an enduring grip on life. There are no short cuts that are worth following.

Of course, it is rather presumptuous for me to talk to this gathering about college education, for personally I was unfortunate enough to escape the vicissitudes of a college education. I can only comfort myself by remembering the dialogue of certain well-known vaudeville entertainers, one of whom tells about his son "Heine" at college who is acquiring a great deal of useless "inflammation" and at last receives a diploma. "A diploma," he explains, "is a paper which you receive when you are through college, you frame it and hang it up on the wall, and then if anybody calls you a big fool you show him the diploma and that settles it."

But life is a college. The practicing engineer is never through studying; and the great question is, have we the capacity to grasp the things around us which will educate and train us year by year throughout all our lives? You will all, probably, agree with me when I say that the true object of college training and education is to furnish us an opportunity, before we begin active life, to learn in some degree to use the tools of life, the mind, the brain and the hand.

Mr. Dow R. Gwinn: There are many people who like to make fun of the college graduate, yet many of those who are so prolific with their jokes know very little about the

experience that these graduates often go through. The speaker has in mind a civil-engineering graduate from Rose Polytechnic Institute, one who graduated at the age of twenty-one. He came out about the time that the railroad companies were shutting off all their outside work, and it was not easy for him to get a position. We put him on our pay-roll at a moderate salary to do some drafting, and he had rather a hard time of it for two years. This boy told me when he came out that he had not averaged over six hours' sleep for the last two years that he had been in college. He had been operating two newspaper routes, one in the morning and one in the afternoon. His mother had worked in an overall factory to help support the family so that she could keep her boy in college; yet when he came out the future was not very bright for him. He had not had enough sleep to give him the proper rest, with the result that he was stunted in growth. It took about two years for him to regain his balance, and those first two years looked very discouraging; but at last he went to Canada and secured a good position with a railroad company where he is making good, having received two or three promotions in the last year.

Mr. W. W. DeBerard:* The ability to add and the ability of adaptation are two points a young engineer should possess along with those theoretical and practical elements of hydraulics, for the teaching of which so many of our larger institutions are so admirably equipped. From the employers' standpoint, the ability to add accurately is a priceless virtue in a young engineer's training, while for his own advancement, an engineer's ability to adapt himself to his surroundings is a characteristic that will carry him far on the road to success.

Adding accurately, and with addition is included the simpler arithmetical calculations, makes an impression on the chief not to be belittled, for few engineers like to promote a new man who gets an average of a series of hydrographic readings nearly as high as the maximum. Misplacing a decimal point periodically after using a slide rule, because one is

* Western Editor, *Engineering Record,* Chicago, Ill.

too stupid or lazy to roughly calculate the result, is likely to cause thoughts on the part of the employer of making the engineer's salary $9 instead of $90 per month. A mistake of a million dollars on a published estimate of the cost of a sewerage system of a large eastern city several years ago was detected just in time by the chief engineer, who took the trouble to total the final summary. A recent report on city-waste disposal in a city of the middle west is so full of similar errors, that one reads the remainder of the report, if he has to, with distrust.

Along the line of adapting oneself to his surroundings and getting on with his fellow workers, one chief engineer always asks those referred to by applicants if he has the ability to fit into an organization and to get along with his associates. To my knowledge, one young man, brighter and better equipped than the majority of young engineers, did not secure employment on an important piece of construction where valuable experience was to be obtained, because it was his disposition to set everyone on edge.

Most of our senior-year courses contain subjects which the engineer may not be called upon to use for many years, if ever. It is common among the old-school engineers to carp at placing these courses in the curriculum and they often express the opinion that the present-day graduates come out of school with the idea of telling the chief how to carry on his work. Much of the early work of the young engineer will be plodding, tedious routine of endless calculations, mapping, hydrographic gagings or surveying. If he can adapt himself to this work the more easily by knowing something of what it is all about and how the problem is being solved in a big, general way, he demonstrates that the berated senior courses have at least served one admirable purpose.

Given the fundamentals, the successful engineer must then proceed to acquire experience, for engineering has been defined as nine tenths experience and horse sense, and one tenth theory. This varied experience can rarely be obtained under one employer but an opportune time for him to change must

be sought with tact and without embarrassing the chief, and frequently without regard to immediate salary increase. To make the topographical map of his brain complete, interesting and valuable to the owner and to others, the hydraulic engineer must occupy in succession first, those stations in the monotonous plains of plodding drudgery with its mirages of possible prosperity, later those stations on the rolling rounded hills of the $100 to $150 assistant engineer's position where the multitudes thrive, fight, are held or are content to gaze on the fascinating mountain topography of the consulting engineers; finally to occupy the promised land of opportunity and originality, with its closely drawn contours of rapid rises and equally steep declivities, leading finally to that broad plateau where grand conceptions coupled with heroic endeavors are molded into the admiring world's most marvelous structures.

In conclusion, picture a camp in a 100-square-mile area of flat country where mirages of beautiful lakes rise on every hand and dancing heat waves make a leveling rod look like a coiled snake standing on its tail. Orders are to occupy every corner of 500 x 1000-foot rectangles and take "shots" at the corners of approximately 100-foot squares because a 1-foot contour map for irrigation purposes must be made. Specific features of education, knowledge or training will have little to do with the success of the young man here. Only natural or acquired enthusiasm, ability to get on with his fellows and adapting his stomach to the Chinese cook's fare as well as to his chief's disposition will carry a man through.

THE NEW BUILDING AT WENTWORTH INSTITUTE AND THE ARRANGEMENT AND EQUIPMENT OF ITS LABORATORIES.

BY ARTHUR L. WILLISTON,

Principal, Wentworth Institute.

At the Pittsburgh meeting of this society, two years ago, the writer presented a paper describing the architectural problem of housing an educational institution like Wentworth Institute and also describing the initial group of buildings and the proposed plan for future development. A few weeks ago a contract was signed for an addition to the plant which will just about double the present working floor space. A description of the proposed building and of the arrangement and equipment of the new drawing rooms and laboratories will supplement the previous paper and will, therefore, perhaps be of interest.

The building for which this contract was let is shown in elevation in Fig. 1. It is 134 ft. long by 66 ft. wide and is a four story building, with a gallery floor above the regular top floor of full working height for laboratory purposes. This building is the central one of the entire group, and will constitute the principal entrance, in fact the only student entrance, to all of the buildings no matter how many more buildings are added. It is connected on the main floor by a broad 12-ft. corridor with the adjoining buildings. In this way a short, direct covered passageway is obtained between all buildings. The buildings are not connected on other floors.

It is believed that this central control of the student body, is similar in a way to the control obtained in a large manufacturing plant, and that the direct covered passage between all buildings and departments are very valuable features of the building arrangement. Students can not enter or leave the build-

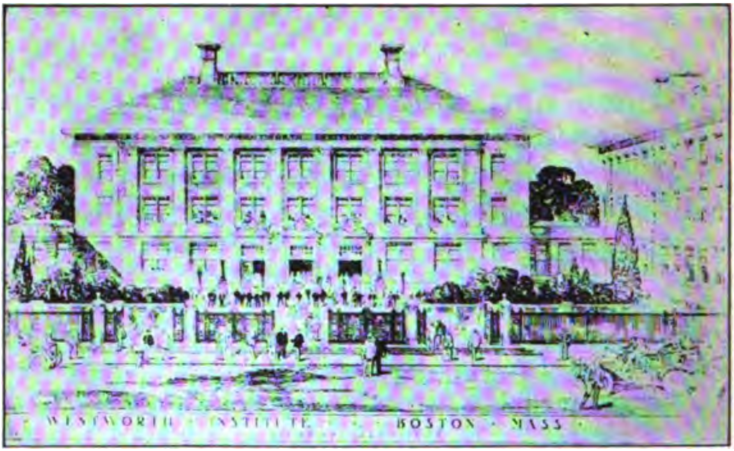

FIG. 1. The Administration Building of Wentworth Institute, Boston.

ings without passing the general offices. They are obliged to pass the general bulletin boards at least twice daily. Habitual tardiness is easily observed and corrected; and in many other ways more effective and efficient control is obtained by the general administration offices than is possible with buildings separated in the usual way. The covered passageway between buildings permits the centralization of wash-rooms, locker-rooms, study-rooms, etc; makes umbrellas and outside wraps unnecessary in going from building to building in inclement weather; reduces the time consumed in going from department to department, and facilitates the transfer back and forth of records, apparatus, and material between closely-related departments. It is felt that these advantages have been obtained without any corresponding disadvantages for, as will be seen from Fig. 1, neither the outlook nor the lighting of the buildings has been appreciably impaired by the connecting corridors, nor has the architectural attractiveness of the group been diminished.

The architects' completed block plan is shown in Fig. 2. All the possibilities of future development which the site permits are indicated here. The building that we are describ-

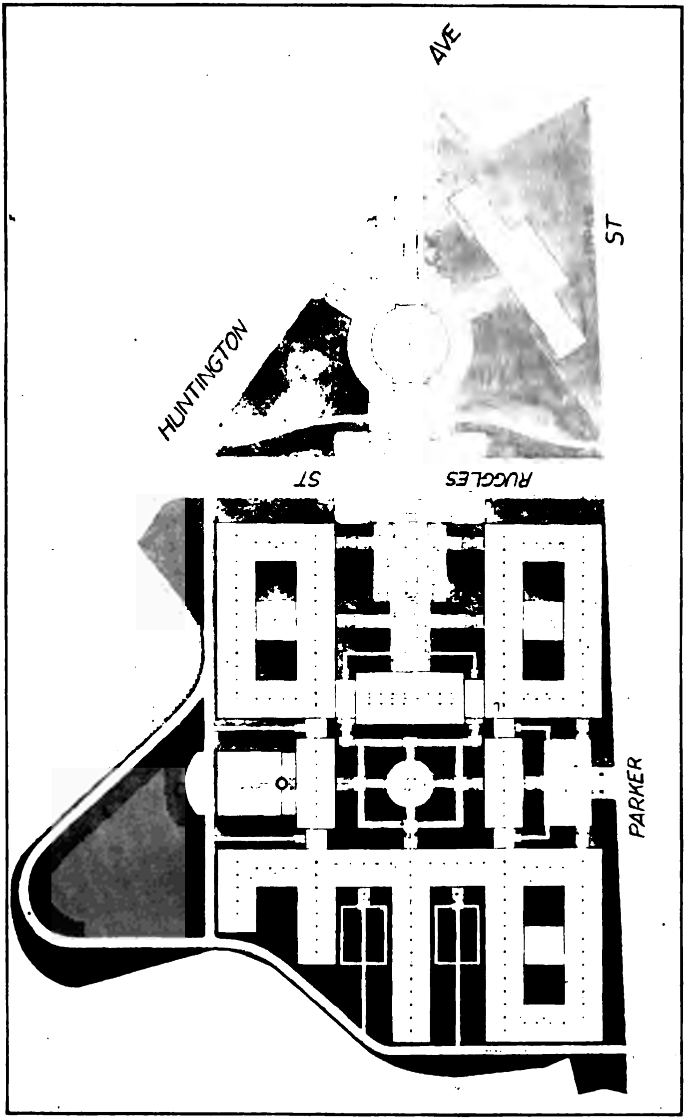

FIG. 2. The Architects' Completed Block Plan.

ing is the central building facing the court-yard and Ruggles street. The triangular area on the other side of Ruggles street and between Ruggles street and Huntington Ave., is to be kept open and developed as a park for the purpose of giving an attractive outlook.

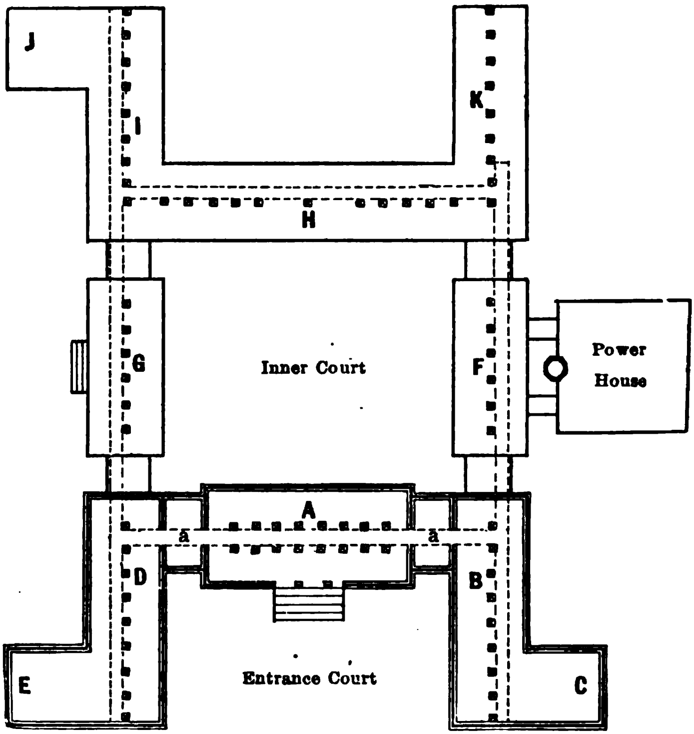

FIG. 3. Block Plan showing Probable Order of Development.

Fig. 3 is a block plan showing that portion of the architects' completed plan which will probably be developed first. "*A*" is the building that we are now describing; "*B*," "*C*," "*a*" and the "Power House" constitute the initial group of buildings completed two years ago. "*D*" and "*E*" are the buildings contemplated next. This plan shows plainly the arrangement of the main connecting corridors referred to above.

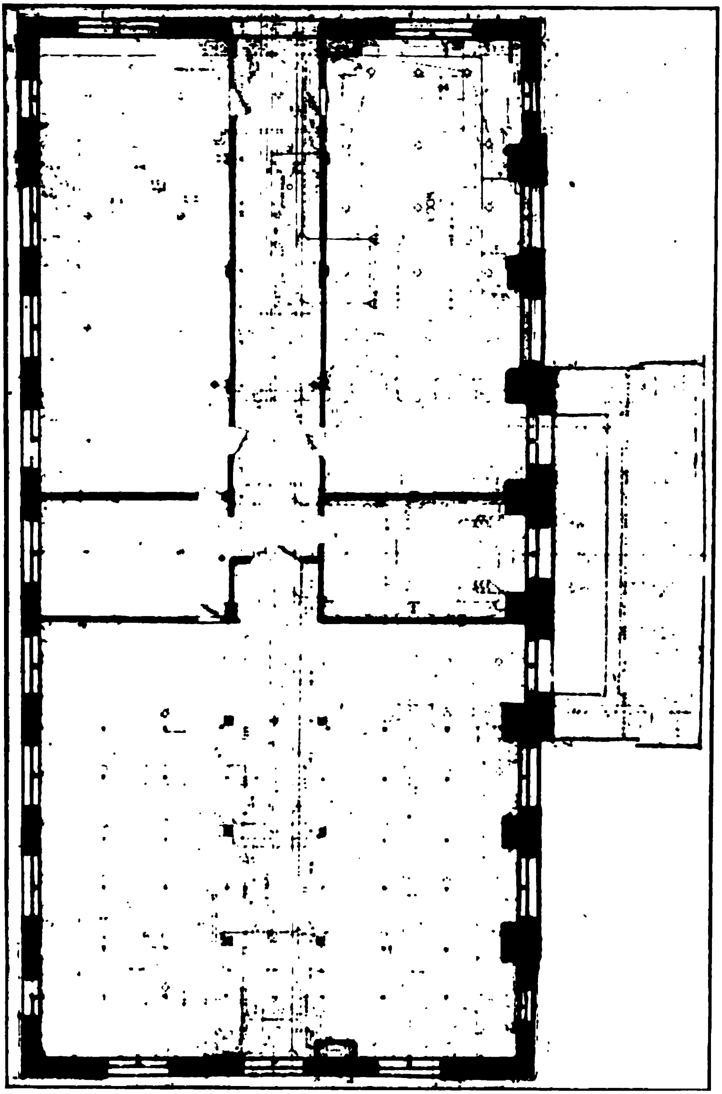

Fig. 4. Ground-floor Plan showing Laboratories for Electrical Power Plant Practice and Materials of Construction.

The arrangement of the rooms and laboratories on the ground floor of the new building is shown in Fig. 4. There is a large laboratory about 60 ft. by 62 ft. with an adjoining office, for work in electrical power plant practice. On the other side of the office there is a second laboratory about 70 ft. by 24 ft. for studying strength of materials and building construction. The remainder of this floor is devoted to a fan room and a large locker- and wash-room.

The second floor, the main entrance floor, is shown in Fig. 5. There is a large lecture-room on each side of the entrance lobby, and the rear half of the floor for the entire length of the building is devoted to general office, principal's office, and offices for other administrative departments.

The whole of the third floor will be devoted to the department of mechanical and architectural drawing and design. This is shown in Fig. 6. There are two drawing-rooms, each about 60 ft. by 24 ft., and a larger drawing-room 80 ft. by 38 ft. The office is located in the center of these three rooms with large areas of glass in the partition walls.

The fourth floor is shown in Fig. 7. At one end is a large lecture-room or assembly hall with gallery, which is expected to accommodate about three hundred and sixty persons. At the other end is the practical mechanics laboratory, office and stock room. Above this laboratory is the gallery floor shown in Fig. 8, which practically doubles the floor space.

A cross section of the building is given in Fig. 9. This shows plainly the gallery floor with generous head room between the trusses, and also the tunnel for steam pipes, electric conduits, etc.

It is expected that the building will be completed in the early spring in ample season for it to be equipped and ready for entering classes in the fall of 1914.

Equipment.

The initial buildings were planned originally to be used almost exclusively for shop purposes, but at present a portion

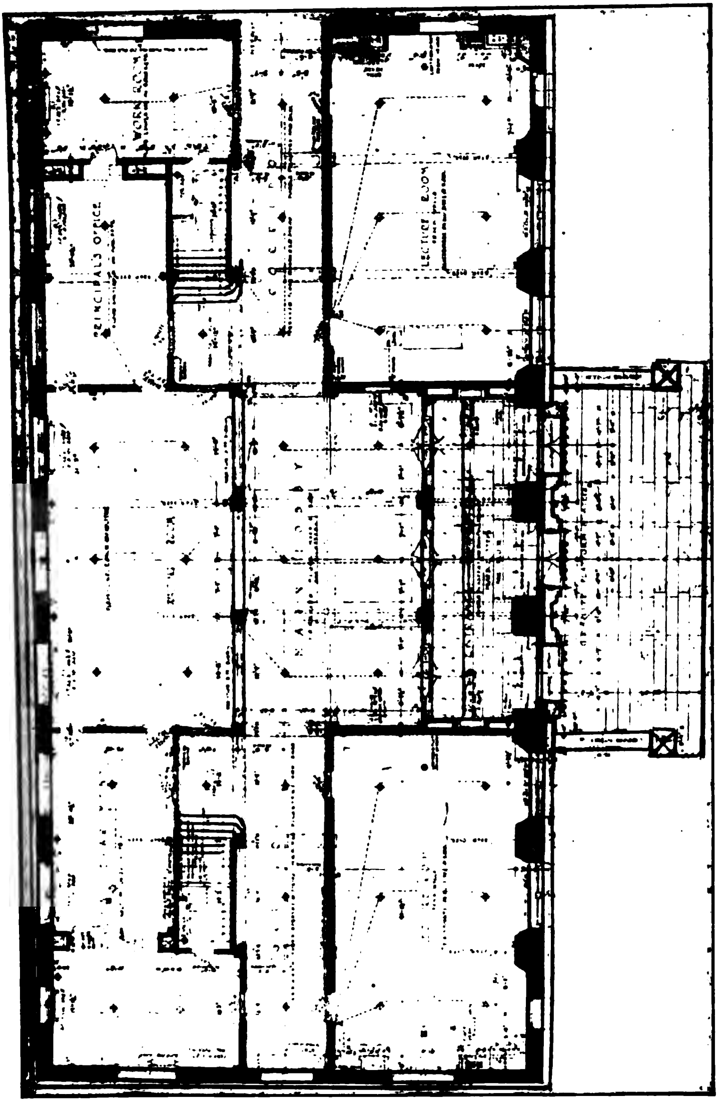

Fig. 5. Second Floor Plan showing Lecture Rooms and Administration Offices.

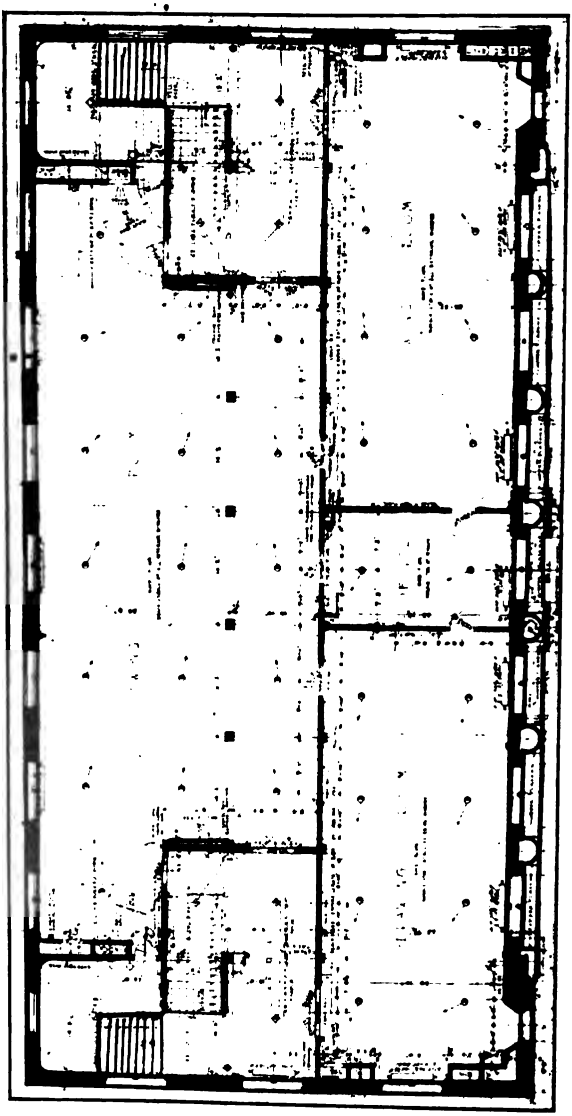

FIG. 6. Third Floor Plan showing Three Drawing Rooms and Drawing Office.

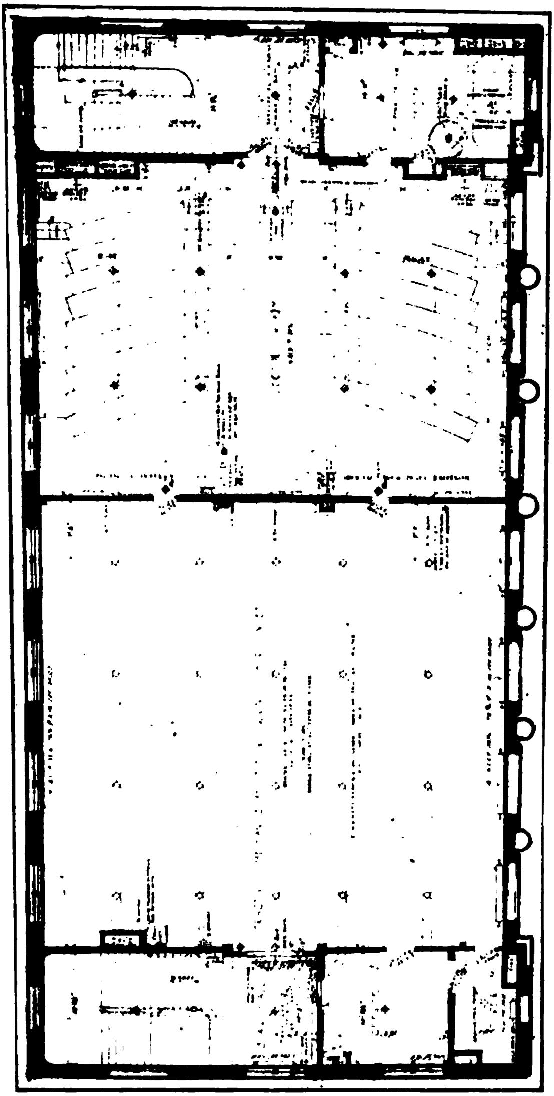

FIG. 7. Fourth Floor Plan showing Assembly Hall and Practical Mechanics Laboratory.

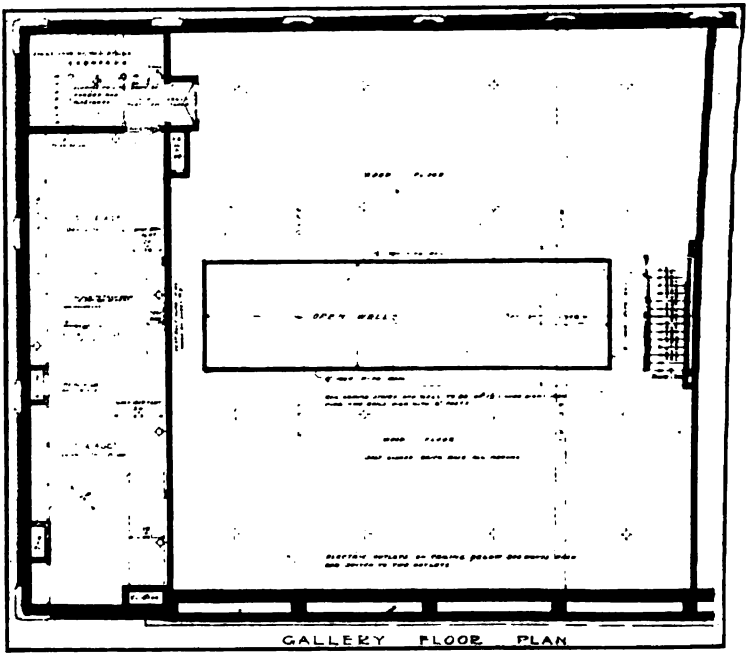

FIG. 8. Gallery Floor Plan showing portion of Practical Mechanics Laboratory.

of the floor space is being used for drawing-rooms, practical mechanics, and strength of materials laboratories and class-rooms. On the completion of the new building these will all be removed, and in consequence it will be possible to very nearly double the present accommodations of all of the shop departments, except the foundry which was originally planned to accommodate from sixty to one hundred students at a time. The removal of the present laboratory for teaching electrical power plant practice from the power house to the ground floor of the new building will make possible also doubling the floor space now devoted to the laboratories of steam power plant practice. In this way the new building permits growth and development in many other departments besides those which it will actually house.

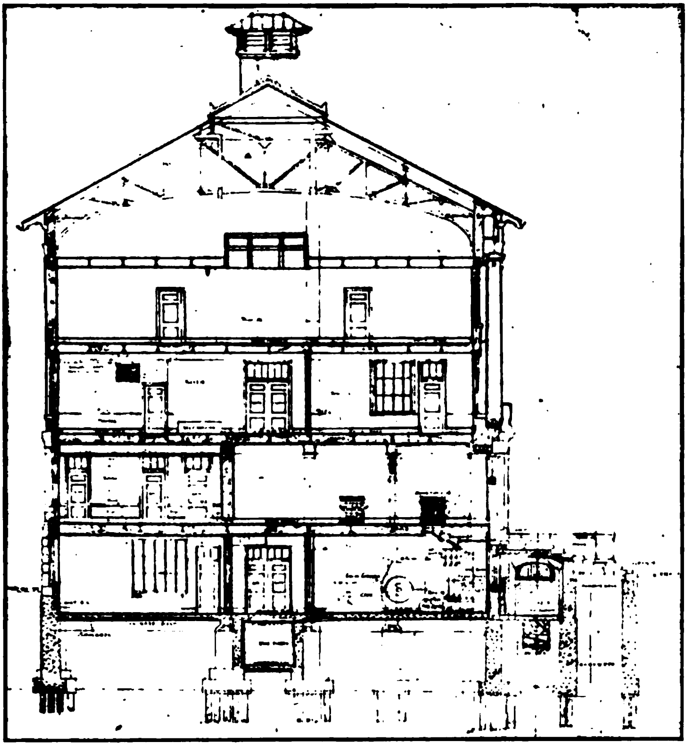

FIG. 9. Cross-Section of Building.

It is the purpose to equip the electrical power plant laboratory with apparatus of strictly commercial type, using units of the various kinds that are met in every day practice. So far as possible, these units will be arranged in motor-generator sets, permanently installed on iron tables with tops of reinforced concrete. The idea is to have each one of these sets as complete as possible, with its own switchboard and auxiliary equipment, and to have it typify, as far as may be, some actual type of power plant, sub-station, or service condition. This new laboratory provides room for thirty of these stations, and some idea of its appearance, when equipped, can be obtained from Fig. 10, which shows a photograph taken in our present

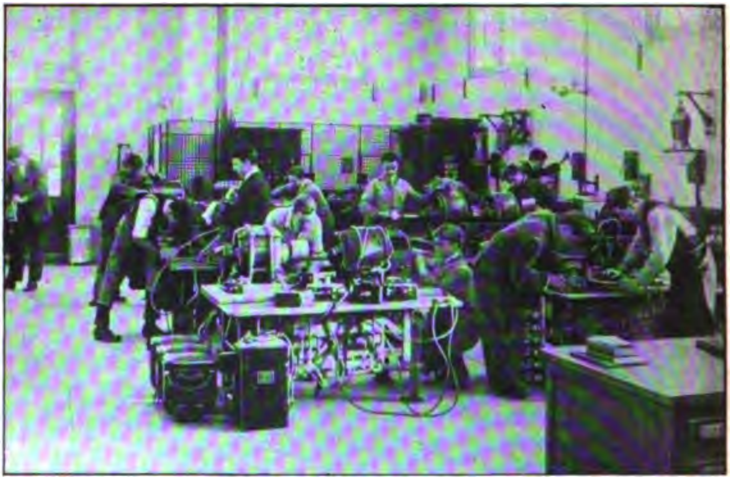

FIG. 10. A portion of Present Laboratory showing the type of equipment planned for new Laboratory of Electrical Power Plant Practice.

electrical power plant laboratory. Here, however, there is room for but ten stations.

The equipment of the building construction and strength of materials laboratory will not differ in any radical way from the corresponding laboratories in many of the schools of engineering, excepting that the apparatus will be selected and arranged with a view to getting results of approximate and commercial accuracy with speed and facility on a large number of types of specimens rather than of striving for scientific accuracy for purposes of research.

In what we call the practical mechanics laboratory there will be more features of distinctive character than in any other department. It has been our aim to base our instruction in each one of the trades, like foundry practice, plumbing, machine work, etc., on a really scientific foundation and to instill into our students enough, at least, of the scientific point of view and habit of thought to enable them to reason accurately from cause to effect, to make them believe that there

are better ways of doing things than have yet been discovered, to make them desire to investigate, and to make them anxious to use methods of eliminating loss.

In each one of these trades there are new sciences to be developed. In some instances the essential facts have been discovered and need only to be simplified, correlated and arranged in orderly, systematic and teachable fashion. In other instances the fundamental facts are largely undiscovered; and in many more the facts and principles are entirely obvious to the trained engineer, but methods have not been discovered of making them easily understood and usable by those who have not had, and cannot take the time to get, extensive scientific training. A few such references as the following will illustrate my thought: Mr. F. W. Taylor's work on the art of cutting metals; Keep's investigations on the shrinkage of cast iron; the strength and heat-resisting powers of cores made with different sands and different core-compounds; the causes that make different kinds of foundry sands suitable for different classes of work; the ability of different types of traps to resist siphonic action; and the simplest working principles for cutting spiral gears, or for determining rake and clearance for millers, reamers, tapping machines, etc. For lack of a better name we have grouped together all of these departments of applied science under the general term of practical mechanics of the various trades.

The problem of developing and of teaching such applied sciences is a complicated one, especially because of the short time that is available and because practically all the information must be given to the student in a form which is both useful and usable in the every day practice of the trades. We have found that the laboratory method of instruction is the most efficient one, and in order to use it to best of advantage, we have separated as completely as possible the instruction in the *productive work* of the trades, which is given in shops resembling commercial shops in their atmosphere as closely as we can make them, from the instruction in the *principles* underlying the trades which we give in a separate department

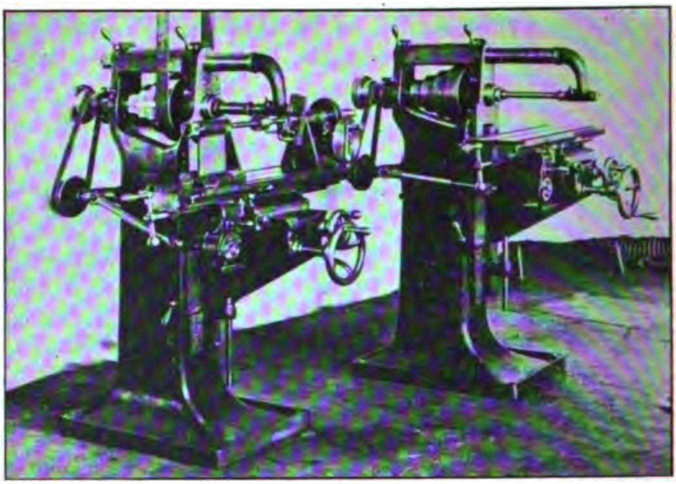

FIG. 11. Two Milling Machines Manufactured by One-year Day Class in 3½ Months and now being Operated.

and under other instructors in our practical mechanics laboratory. In order to illustrate how distinct we are keeping these departments and yet how closely correlated we are keeping the two, I would call attention to Fig. 11 which shows two milling machines manufactured by our one-year day class in machine work. These machines were entirely completed, including all the special boring-bars, counter-bores, reamers, taps, jigs, etc., that were necessary in their construction, and were being operated within less than three and a half months from the time in which the castings were delivered to the shop. Here emphasis was placed upon speed, accuracy and perfection of production. Fig. 12 shows a portion of the same class in the practical mechanics laboratory studying gear changes of an F. E. Reed engine lathe necessary for cutting different threads, the efficiency of the worm and worm wheel, the friction of a belt drive, the change speed gear-box, and the friction of the counter-shaft of the speed lathe. Here the emphasis is entirely upon teaching principles and upon cultivating the scientific spirit already referred to. It will be noticed,

FIG. 12. A Portion of the One-year Day Machine Class in the Practical Mechanics Laboratory.

however, that the two lines of work are correlated almost as closely as if they were given by the same instructor in the same room.

Fig. 13 shows a corner of the practical mechanics laboratory in which carpenters and builders are learning something of the principles of roof trusses, hoisting tackle, and cranes.

Figs. 14 and 15 show two views of the portion of the same laboratory devoted to plumbers. Here we see students testing the siphonage of traps, the discharge of water under different pressures and through different sized pipes, the resistances of a large number of right-angle bends in the water pipe line, also the comparative resistance to flow of different sizes of supply pipe, and, in Fig. 15 at the right, a student testing a gas water heater and the comparative efficiency of two common methods of piping the same to a common kitchen boiler.

Other illustrations could be given to show the character of the equipment that is being designed to teach the various principles that are essential in the trades referred to and in all the other trades that are included in our different courses of study.

FIG. 13. A Portion of the One-year Day Class in Carpentry in the Practical Mechanics Laboratory

Enough has been shown, however, to suggest the general type of the apparatus that we are planning to use in equipping the practical mechanics laboratory on the fourth floor and gallery floor of our new building.

DISCUSSION.

Professor G. R. Chatburn: Will Professor Williston please tell us what the area of the site owned by Wentworth Institute is, and how much of it is now covered by buildings.

Professor A. L. Williston: There are about thirteen acres in the site and it is approximately thirteen hundred and fifty feet long and has an average width of about four hundred and sixty-five feet. There is room on the site for about twenty-four buildings of the size of our standard *"unit."* In our present group of buildings there are two and one-half units or about one-tenth of the total that there is room for ultimately.

Professor Chatburn: How many students do you expect to be able to accommodate in the end?

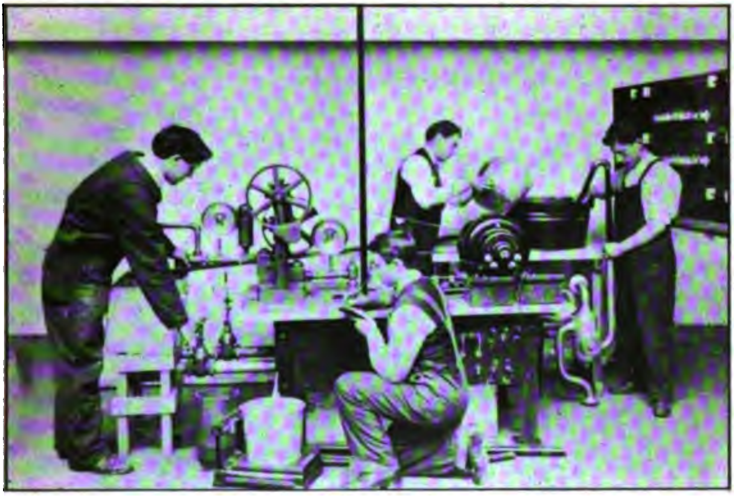

FIG. 14. A Portion of the One-year Day Class in Plumbing in the Practical Mechanics Laboratory.

Professor Williston: The future only can give a definite answer to that question. We can accommodate comfortably six hundred day students and nine hundred evening students in what corresponds to about three of the twenty-four possible buildings. If an institution like Wentworth Institute can be operated as economically regarding floor space when it has become large as it can while it is small, it should be possible to provide for nearly five thousand day students and seventy-five hundred or eight thousand evening students. As time goes on, however, we may find that more floor space is required per student.

Dean C. M. Woodward: Am I correct in assuming that Wentworth Institute is an independent institution with no organic relation with any other school?

Professor Williston: It is entirely independent. We have an endowment of about $3,500,000 which was bequeathed us by Arioch Wentworth, a successful marble manufacturer of Boston. Thus far, our site, buildings and equipment have

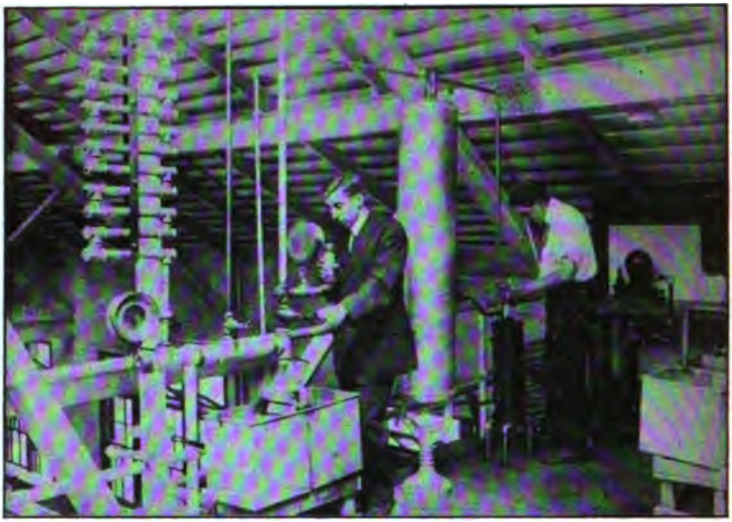

FIG. 15. Students in Plumbing testing flow of water in pipes, friction of fittings, and efficiency of a gas hot-water heater.

been purchased from our income. Our original endowment, therefore, still remains intact.

Dean F. L. Bishop: Will the speaker please tell us what education and school training is required for admission.

Professor Williston: The boys must be at least sixteen years old. No entrance examinations are required for what we call our "trade courses." Examinations in arithmetic and English are required for what we call our "foremanship courses." All students, however, are required to satisfy the principal, in a personal interview, that they have the natural intelligence and the qualities of mind and character that are needed for success in the particular trade that they wish to enter. Many of the applicants have not completed even a grammar-school training. Usually they have gone to work before completing this and have either become dissatisfied with the opportunity for promotion, or, because of exceptional ability and ambition, have been persuaded by employers or friends to go to a school like Wentworth Institute. Very frequently they have saved

the money needed for this purpose from their own earnings. They are, therefore, in the main, young men with exceptional ambition and initiative—fine diamonds in the rough—but, so far as formal school training is concerned, they have had but very little.

Mingled with these exceptional fellows are a considerable number of boys of distinctly poorer fiber who nevertheless learn to do well by being brought in competition with their more enterprising and forceful comrades. On the other hand, there are a number of high-school graduates among our students who feel that they can afford only the shortest possible time for practical training before going to work They come to a school like ours because a full college course is for them impossible.

The financial problems that a great majority of our students have to meet are very serious. Practically all of them work Saturdays and holidays to help pay their living expenses, and some of the sacrifices made are very severe.

Dean Bishop: I should like also to know what encouragement, if any, is given to the students in Wentworth Institute to enter engineering schools after they have completed their courses there.

Professor Williston: It happens once in a while that it is possible for one of our graduates to go to college; and such a student is always encouraged to do so. One will go this year, and if I remember rightly, one went last year. These cases, however, are rare. It is possible, as a rule, only through some unexpected good fortune which changes the family circumstances and thus makes possible the funds that are needed. I suppose this happens to perhaps two or three, or possibly five per cent. of our graduates. Almost every boy who has succeeded in going to college has made a very creditable record.

Dean Adolph Shane: I should like to ask what courses are now being taught at Wentworth Institute and how long it takes to complete them on the average.

Professor Williston: At the present time we have six one-year day trade courses; three in the building trades—plumb-

ing, electric-wiring and carpentry and building; also three of similar character in the manufacturing trades—machine work, pattern-making and foundry practice.

In addition to these one-year trade courses, we also have two two-year courses which we call *"foremanship courses."* These are intended, as their name indicates, to train foremen, master-mechanics, superintendents of production departments, and men for similar positions of grade between that of the skilled mechanic on the one hand and that of the engineer on the other.

One of these "foremanship courses" is a mechanical course for the manufacturing industries dependent on the machine trade. The other is an electrical course for a large group of electrical positions connected with the manufacture, installation, and operation of electrical machinery and apparatus, and requiring technical knowledge and practical skill beyond that possessed by the skilled mechanic.

Besides the day courses, we are now offering seventeen evening courses. In some of these we teach the mechanical side of the trade and give experience in handling tools and machinery. In others we teach technical subjects such as estimating, practical mechanics, blue-print reading, shop sketching and similar things that the high grade mechanic or foreman needs to know.

Dean Shane: I would also like to ask whether the young men who finish these one-year day courses are full-fledged mechanics in their lines of trade; and how they compare with men who have learned their trade in other ways.

Professor Williston: It is difficult to answer that question in a few words. In a nine-month course we cannot do all the things that are done in an apprenticeship of four years for any except very exceptional boys. We have, however, had some boys who have come to us with no previous experience in the trade and who have gotten in nine months the full equivalent of the average four-year apprenticeship. At the end of nine months such boys have been able to hold their own at the start with experienced journeymen mechanics. But very few

boys can do this. The reason is not altogether because they do not know enough or are not skilled enough, but because they are immature, lack self-confidence and do not dare go out and demand a journeyman's job. They still lack some of the things that come from contact with men. As a rule, a certain period of apprenticeship is necessary before our graduates can hope to command journeymen's wages. The length of this apprenticeship varies with the boy. On an average, I believe that our nine-month course is equivalent to from two years and a half to three years of apprenticeship in an ordinary shop. In addition to this the likelihood of rapid promotion and ultimate advancement to positions of responsibility is much greater for a boy who has studied in a trade school than for one whose training has been wholly in a shop.

Dean Woodward: How do the unions regard your work?

Professor Williston: Theoretically, the unions are still opposed to private trade schools on the ground that there are in them possibilities of abuse. But practically, so far as we have been able to discover, the relation is a most cordial one. The individual members of the union, so far as they know anything about it, recognize almost invariably that the kind of work we are doing is tending to increase the standards of intelligence and workmanship in the various trades, and consequently is tending to help everybody connected with them. They realize, I believe, that we are doing honest work and are endeavoring to develop superior men and, consequently, we do not come in for the general condemnation which they are ready to bestow on certain private schools that have from time to time tried to turn into the trades men who are superficially trained and willing to work for cut prices.

Dean Woodward: The reason for asking this question is that in the early days when the manual training of Washington University was the only work of that character in the country, the union committee used to come to us and ask questions. They would look over the work in the forge shop, for instance, and ask how long the boys worked there. We would reply, "Two hours per day for three days in the week, a total

of six hours per week." Then they would ask the number of weeks and would be told that the course continued for twenty weeks. By simple arithmetic, they would conclude that the boys had an equivalent of about fifteen full days work; and would look at each other and say, with a smile, "Well, we do not think that amount will hurt them any."

Dean Shane: When visiting Wentworth Institute a year ago, I noticed a few model houses that had been built. They were in skeleton form, without weather-boarding in many cases, and represented an actual illustration of real houses. I judged from the appearance of those houses that they were constructed about the same as though they were full-sized in every detail. I was so much interested in them that I decided to include similar work in our course at Highland Park College, and we find that it has created a great deal of interest. Now I should like to ask Professor Williston if he has been able to do anything similar in the machine trade. In other words, does he depend entirely upon exercise work or does he build real things? Does he devote all the time to showing the students the "principles of how to do things," or does he actually have them do constructive work?

Professor Williston: In addition to the model houses built in our course in carpentry, we build a great many other real things. Some of these are on a somewhat reduced scale, like the houses referred to, but most of them are full-sized. We take each important section of a house, such as a door or window casing, an outside cornice, a section of floor or wainscoting and mantelpiece, and have each completed in commercial fashion.

In the machine shop we are able to do still better, because the variety of work that is possible is greater, and because little or none of the product has to be destroyed. Our first exercises are roughing out of machine parts that will afterwards be finished to exact size and used productively. Some of the things we make are comparatively small and consequently can be carried through in large lots. For example, we are making fifty planer vises of our own design. Some of

the other things we undertake are more pretentious, such as the two milling machines that I showed a few moments ago on the screen. These machines were completed and were in operation in less than three and a half months from the time the castings were delivered.

The work in machines of this kind is carefully analyzed. The simple parts are given to the students first. Those that require greater care and accuracy come later. The exact fitting, and those parts that require the exercise of most judgment, are saved until the last after the class has acquired some skill and experience. This year we are manufacturing two dozen 24-inch back-geared and power-feed drill presses.

We are planning to sell our product. Thus far we have sold comparatively little because we have needed everything that we could make for our own equipment, but I do not think there will be any difficulty in disposing of whatever we can produce at satisfactory prices.

Dean Shane: Do you teach students to do things rapidly, or simply teach them to do things well?

Professor Williston: We do both. At the start we emphasize quality but later we pay much attention to developing speed and to time-studies that enable the students to make economies of both time and physical effort.

Dean Shane: I would like to ask how much time is devoted to training in the shop and how much is given to other branches.

Professor Williston: Our days are eight hours long and are divided into two equal parts. One half the time is spent in the shops acquiring skill and gaining shop experience. Our day in the shop is short and we make it intense. We keep the boys on the "tips of their toes" from the start to the finish; and at the close of the four-hour period come pretty close to getting eight hours worth of product. The other four hours are spent in the drawing room, laboratory or lecture room; and after the work in the shop, the boys are delighted to have this kind of change of occupation. In this half of the day we develop what I call the "Why" side of education. In the shops

we teach the "How." In all the school work in the afternoon we keep the instruction very strictly related to the work in the particular trade in the shop in the morning. We try to make it answer the questions that are naturally raised in the boy's mind while he was doing his productive work.

Professor W. H. Meeker: It would be interesting to have Professor Williston tell us where he gets his instructors, what kind he finds most efficient and whether he uses the same men for the instruction courses in which the students are taught the "How" as he does in those where the students learn the "Why."

Professor Williston: We do not use the same men for the two classes of work. As a rule, we use totally different types of men. The men who can best explain the "Why" are, in a majority of cases, men who could not create in the shop the atmosphere that would command the respect of boys who had seen real work. In the shop we want men who can make such boys feel that here is the finest atmosphere of industry and production that they have ever seen. Men who teach the "Why" cannot often do this.

It is very hard indeed to find the right kind of men for a school like Wentworth Institute. One of the best of our men, I am happy to say, came from the University of Minnesota. Professor Eddy has just signed his application for membership in this society. He learned his trade as a foundryman in Minneapolis. He became assistant in the foundry department at the University here. While he was instructor, he made arrangements for study in his spare time. During a period of nearly six years he took practically all of the chemistry that was then offered by the Department of Chemistry that was in any way related to his line of business. Later he became the head of the Foundry Department of the Winona Technical Institute at Indianapolis. From there he came to us.

This example may be regarded as typical of the majority of our men. They have had extended experience in shop practice and often in shop management. They have seen enough of school methods to know something about teaching; and they

have had opportunity for advanced study in one way or another, that has made them, to some extent, authorities in their own particular lines.

Professor B. B. Brackett: I would like to ask Professor Williston if there is any demand for, or if there is any possibility of successful work of a kind like that at Wentworth Institute except in large cities and manufacturing centers. Is there any reasonable probability of doing such work in small towns or cities? Personally, I know of one instance where an attempt was made in a town of about four thousand inhabitants to establish a school founded upon the experience of Pratt Institute. The man in charge of it came directly from Pratt Institute. The work, however, did not succeed. I was not intimately acquainted with it at the time, but I have had considerable doubt as to whether the failure was due to the man in charge or to other conditions. I am inclined to think the lack of success was due to the other conditions.

Professor Williston: The economic problems that have to be met in industrial education are very, very serious, even when the conditions are most favorable. Away from industrial centers, these problems become more serious. I would not say that a successful industrial school in a small village away from the industrial center was impossible, but its chances of success would be small. It would be necessary to have much greater ability in the teaching staff and more complete and attractive equipment, in order to make up for its unfortunate location. To a large extent it would have to draw its students from a distance and its work would consequently have to appear especially attractive to make the students willing to live in the place where it was located in order that they might attend.

The usual experience is, whenever an experiment in industrial education is tried in a small place, that instead of realizing the necessity of doing better work than would be required in an industrial center, the authorities believe that they need to do much less. Too often they say that "This is but a small country town; we do not need much here. A low salaried

man ought to be sufficient for our work. We do not need to start out on a large scale in order to command respect, etc." This may explain the reason for the failure that Professor Brackett has referred to.

The boys who enter industrial schools almost always come from families that really need the added income that they could have if the boys were to go to work instead of attending school. The sacrifice that has to be made in order to permit them to attend school, even where they may live at home, is consequently a very genuine one. In many instances as small a matter as the difference between a five and a ten-cent car-fare determines the possibility of school training. In comparatively few cases is it at all practicable, therefore, to add to the other sacrifices, those of travelling expenses and board bills away from home—and even in these few cases the certainty of benefit must be great.

THE REVISION AND STANDARDIZATION OF ENGLISH TECHNICAL TERMS.

BY D. M. WRIGHT,

Secretary and Treasurer, The Henry & Wright Mfg. Co., Hartford, Conn.

That the nomenclature of the English language can be vastly improved in practically every art and industry must be conceded by any thoughtful person; but in no department of the language, perhaps, is the need of revision more clearly illustrated than in the nomenclature of mechanical engineering. This for purposes of discussion may be divided into four parts: Names of metal-working machines, names of tools, names of parts and general terms employed by metal-workers.

About two years ago, at the first hearing before the Senate Finance Committee in Washington of the so-called machine-tool builders in protest to the reduction then contemplated in protective tariff on their product, it was demonstrated that there was only a very vague idea of what a so-called machine tool consists. This confusion of understanding was further apparent from the fact that, while the manufacturers in a general way maintained that their product was a class of machines for working metal, it was impossible to define the line between their machines and others called metal-working machines, which were by some strange freak protected by a higher duty, although employing under similar conditions the same class of workmen. It can readily be seen that this confusion makes it possible to juggle names in the custom house, so that when it is convenient, any kind of machine for working metal can, by insistence, be classed either as a metal-working machine or a machine tool. Abundant proof is not lacking that this has been done to an extent that has amounted to a loss representing a comfortable fortune to the government each year and a direct advantage to foreign shippers. This

has meant another large loss to American machine manufacturers. Many other illustrations might be given of the direct financial injury which results from the use of crude nomenclature, not only in mechanical engineering but in every art and industry.

When a whole division of such an important profession as mechanical engineering cannot clearly describe its product, is it not time that something should be done? What difficulty is there in the way? Simply precedent springing from an acknowledged ignorant source.

An effort has already been made to refine mechanical nomenclature, with such good results that a description of what has been done may promote interest in other departments of the language, and if finally a concerted effort were made to promote the use of preferred nomenclature in all the professions, this would certainly lead to the publication of text-books and a dictionary of preferred English nomenclature. Such concerted action would be of tremendous benefit not only as a refining agent, but also as a means of promoting a clearer understanding and a more accurate translation of the language, for one of the most important results of improvement in our nomenclature would be the commercial advantage of eliminating possible misunderstanding of terms in translation as well as in the custom-house, in the courts, among students of the professions and among the general public.

Now most cases of ambiguity arise from the failure to use specific terms. Take, for example, the name "machine tool." An analysis shows that a machine is a mechanism for automatically transforming energy into the various quantities and directions necessary to fulfill the purpose of its design, while a tool is an implement with which to work. If these two definitions are accepted, a machine tool cannot be a machine unless it is made to cover every possible machine that employs a tool in its work, but it may be a tool and correctly describes any tool that is used by a machine in distinction from those used by hand, and this division leads to very easy and clearly understood classifications of all machines and tools.

The machines may be generally classified in accordance with their field of operation as follows: Metal-working machinery, wood-working machinery, clay-working machinery, leather-working machinery, stone-working machinery, silk-working machinery, cotton-working machinery, wool-working machinery, etc.

The general classification may be largely subdivided, but always with a clear understanding of the principle governing this general classification. It will be found necessary to change materially many of the common names of machines, as some of them are more or less meaningless, and consequently untranslatable, while others are very crude.

A few examples of preferred nomenclature in metal working machines will illustrate the point: Drilling machine instead of drill, driller or drill press, milling machine instead of miller, turning machine instead of lathe, boring machine instead of boring mill, grinding machine instead of grinder, planing machine instead of planer, dieing machine instead of power press, shaping machine instead of shaper, slotting machine instead of slotter, shearing machine instead of power shear, sawing machine instead of saw, etc.

The idea is always to call a machine first a machine and then give it a descriptive name that will tell what it is designed to do.

The words describing the position in which the machine works should preferably be of single meaning, such as vertical and horizontal instead of upright and laydown. When it is desirable to describe a multiplicity of operations of a machine, more than a single descriptive word may be required. For example, "automatic multiple-spindle turning machine" is preferable to "automatic multiple-spindle screw machine," the word "turning" being substituted for "screw" as the machine in question performs so many other turning operations besides turning screw threads, that screw machine does not adequately describe its work. Thus the name of the machine undoubtedly suffers in translation into foreign languages more than the makers realize. Enough has been said to show

the advantages of improving the nomenclature applied to metal working machines. Let us now consider the second part of our subject, the improvement in the names of tools.

While it may be such a large task as to render it impractical to standardize many of the hand-tool names at present on account of their more ancient origin, it should be a no more difficult task to standardize the machine-tool names under the same system, than it is the machine names. A few examples will illustrate the idea: Drilling tools instead of drills, milling tools instead of cutters, turning tools instead of lathe tools, planing tools instead of planer tools, shaping tools instead of shaper tools, grinding tools instead of wheels of various kinds, sawing tools instead of saws, dieing tools instead of dies or punches, shearing tools instead of shear blades.

That considerable recognition of the value of the improvement in mechanical nomenclature has already been made is shown by a comparison of the indexes and editorials and, in a large measure, the catalogues and advertisements of today with those of five years ago, for in fact the magazines have been of more assistance in the work than the mechanical engineering profession at large. Next in importance to the use of preferred nomenclature in describing machinery and tools comes the description of machine parts, where a more surprising confusion exists than may have been realized without careful investigation. A recent number of a mechanical publication showed the result of an investigation along this line regarding the parts of a turning machine, more commonly known as a "lathe."

The method of investigation used was to submit a picture of a machine, with all its parts dissected and numbered, to a long list of machine makers, with a request that the names used in their factory to describe the parts in question be sent to the investigators. The result showed a multitude of more or less crude and untranslatable names for practically every part; and without doubt, a similar investigation of every other machine will show similar results. Can there be any question in the minds of thoughtful men of the tremendous benefit that

a clearing up of this situation by means of standardization growing from the general adoption of the preferred names would mean to students, engineers, manufacturers, the courts, the custom houses, the public in general, and the dignity of the English language?

After what might be termed the mechanical element is considered, the natural inclination is to throw the same light of investigation on what might be called the human element of the profession. Here again the same crude condition of the use of nomenclature is found.

The sign "No help wanted" is displayed continually in front of thousands of places of business, when the concerns in question are spending collectively millions of dollars daily in the strenuous effort to induce the public to help them by purchasing their goods. How much more truthful and dignified the signs would appear if they read "No more employees needed at present." Then we come to the general reference to employees as "Hands," a specified number, as for instance fifty men, being commonly referred to as fifty hands, regardless of whether they have one or two hands; employees are called planer hands, lathe hands, drill hands, etc., instead of planing, turning and drilling machinists. In looking over this phase of the situation, we come to the word forger, and the layman or foreigner wonders why we are allowed to engage men to copy signatures. The use of the term metal forging machinists would clearly indicate what was meant.

All the old familiar objections which spring up with every effort at reform are offered against preferred nomenclature, such as the magnitude of the effort required to accomplish satisfactory results, the opposition of precedent, etc. There is no doubt that the work to be done is tremendous and perhaps somewhat thankless, but the results already accomplished show what may be done by even a slight effort of a very few people. It is suggested therefore, that as the work is altogether educational, the Society for the Promotion of

Engineering Education should be one of the leaders in carrying it on, and with that end in view, the following is offered:

Resolved: That, inasmuch as there is a decided need for the promotion of the use of preferred nomenclature, the Society for the Promotion of Engineering Education appoint a commission to consider and carry on the work through text-books, publications, by precept, and example, and in any other way deemed proper by the Society.

That the commission be made large enough to spread the interest in its work throughout the land.

That the commission be requested to submit reports of progress at each annual convention.

It is earnestly urged that this subject and resolution be given careful consideration, as there can be no doubt in the mind of any thoughtful person of the magnitude and importance of the work; and the Society, if it recognizes its importance, should not refuse to recognize its obligation in the matter.

DISCUSSION.

Professor J. J. Flather: I fully appreciate the difficulties which the writer has presented in this paper. In my class work, and in shop economics in which the matter of time cards is presented, I have for a number of years past pointed out the difficulty of keeping track of the cost of a machine, because of the different names which will be given to the different parts by the men working on those parts, even in the same shop. Generally, in a given locality we find local technical shop names applied to certain parts of a machine, and these are fairly well understood locally. But even in the same shop we find men applying different terms to the same machine part, so that when charges of time against different jobs are to be made on time cards, there is apt to be confusion. In some cases as many as five or six different names for the same piece are thus entered. The time clerk, who is often not a mechanic, does not understand that the same piece is referred to under different names. For that reason symbols have come to be

used very largely in the shops in keeping account of the men's time on certain parts. It is not necessary in these cases for a man to name the part or even the machine on which he is working, it is simply a matter of symbol. There are times, however, when it is necessary to have a name for every piece. For example, you cannot speak of "257" and convey a definite impression to everyone of what is meant. The workman and the bookkeeper simply charge up time to "X 257," and the cost can be obtained from that, but the name is necessary in some cases. The standardization of these technical terms is, therefore, very desirable.

Dean C. M. Woodward: Mr. Wright has given a great deal of study to, and has been much exercised over, this whole matter of the different names of machine parts. He feels that when one person calls a thing the head-stock of a lathe that other people in the same line of business should know what he means. That is an extreme case, because that particular part of a lathe seems to be pretty well standardized as to nomenclature. But in a blind-stitch sewing machine for example, or some kind of an automatic tool, most of the different parts have no fixed names, and there is no source of information as to custom in connection with the name.

Professor Flather: Mr. Chairman, referring to this resolution, I have modified it slightly and will recommend that it be adopted by the Society. I move the following resolution: That, inasmuch as there is a decided need for the promotion and use of a preferred nomenclature, the Society for the Promotion of Engineering Education appoint a committee to report back to the Society any recommendations that it may deem proper in order to effect an improvement in technical nomenclature.*

* The motion was seconded and adopted.

RECOMMENDATIONS CONCERNING THE UNITS OF FORCE.

BY EDWARD V. HUNTINGTON,

Assistant Professor of Mathematics in Harvard University.

1. **The difficulty in regard to force, mass, and weight.**—The most casual inspection of our current text-books in mechanics will convince any reader that the fundamental relations between force, mass, and weight, as ordinarily presented, must be thoroughly perplexing to the beginner; and every teacher of elementary mechanics knows well that this is the fact.

The comparatively trivial matter of the choice of units occupies much too prominent a place in the ordinary treatment, and "difficulties about units" are too apt to obscure, in the student's mind, much more vital portions of the subject.

2. **The main source of the difficulty** has been the insistence on certain unfamiliar quantities, like the "poundal," the "gee-pound," or the "slugg," as the only scientific or "absolute" units of force or of mass. The very natural and proper difficulty which a student finds in understanding why these strange units are supposed to be necessary is a frequent source of discouragement.

As a matter of fact, the only reason for introducing these units is the desire to preserve the validity of a certain equation $F = ma$, which is *not*, as it is so often called, the "fundamental equation of dynamics," but is merely a special case of that equation, and is useful only in certain special problems, in which certain special systems of units are employed. The widespread habit of regarding this specialized equation $F = ma$ as the most important fact in dynamics has done more than any other one thing to bring about the present confusion

in regard to the units of force and mass.* It has been a Procrustean bed on which all systems of units have been stretched, regardless of any considerations of convenience or common sense.

The absurd lengths to which well-known writers have been carried by their blind allegiance to this equation $F = ma$ is strikingly illustrated by the following quotation from a standard treatise, which ran through many editions both in German and in English, and is still often cited as an authority:

"The mass of a 20 lb. heavy body is 0.62 lb.; and inversely, the weight of a mass of 20 lbs. is 644 lbs."†

This is of course an extreme case; but statements almost as confusing can be found in many of the more modern text-books. Only the lack of space, and the desire to avoid the invidious distinctions always involved in random selections, forbid the citation of passages from current books. Suffice it to say that the difficulty in question is a very real one, which seriously hinders the progress of many intelligent students.

3. The best way out of the difficulty is the return to the simple historical method.

Ever since men have had occasion to measure accurately the magnitudes of forces, the natural and obvious unit of measurement has been *the force required to support some standard body against the downward pull of gravity in some standard locality.* Thus the "gravitational units," such as the *pound force* and the *kilogram force,* are the units of force which are regularly employed by engineers and all other practical men. Moreover, on account of the ease and accuracy with which these units can be reproduced at any time, they are the fundamental units of practical metrology, in terms of which, in the last analysis, all other units are expressed.

There is, however, one unfortunate circumstance connected with these gravitational units of force. Writers have not

* See the trenchant remarks on this subject by Sir George Greenhill, in his "Notes on Dynamics," page 47.

† From Weisbach's "Mechanics."

always agreed on the "standard locality"—some choosing London, some Paris, etc.—and many writers have even neglected to mention the standard locality at all. Since "the force required to support a given body" varies in different localities, any uncertainty in regard to the precise locality intended in the definition is obviously fatal.

On this account, the gravitational units have fallen into some disrepute, and are often described as "variable units," which may be "good enough for rough engineering practice," but which should, we are told, be replaced by the so-called "absolute" units whenever any precise measurements are in question.

For example, in A. Daniell's well known "Text-Book of the Principles of Physics," page 23, we find the following paragraph:

"The engineer's unit of Force is the Weight of 1 lb. or that of 1 kilogramme. He accordingly speaks of, say, a 'Force of 8 lbs.,' where the physicist would say a 'Force equal to the Weight, at some particular place, of a Mass of 8 lbs.' His unit of force is therefore a variable unit, whereas the physicist's unit of force does not in any way depend on local variations in the force of gravity. . . . Still, if properly understood, such expressions as 'a Force of 8 lbs.' are compendious and not wanting in convenience, . . . and the error which they may introduce, through the variability of the engineer's unit of force from place to place, is practically well within one half per cent."

This criticism is entirely valid when directed against certain very prevalent misrepresentations of the gravitational units; but it loses its force entirely when these units are properly defined. The work of the International Bureau of Weights and Measures leaves us no longer in doubt as to what should be meant by "the standard locality," and the restoration of the pound force and the kilogram force to their rightful places as units of force in elementary mechanics would do much to relieve that important subject from the incubus which it now carries.

The purpose of this paper is to urge the importance of a general agreement in regard to the units of force. A list of eight specific recommendations will be given at the end of the paper.

4. **Forces, as measured by a spring balance.**—In the first place, let us agree that a *force* is anything of the nature of a *push or a pull* (in whatever direction the push or the pull may be exerted), and that the natural instrument for measuring forces is a *spring balance.*

The problem then is: What is the unit in which a spring balance should read? That is to say: How shall we define the physical force which will stretch the spring of a standard spring balance to the point marked "1" on the scale, so that it can be reproduced at pleasure?

5. **Definitions of the principal units of force.**—The principal units of force in English-speaking countries are, or ought to be, defined as follows:

The *standard pound force* (1 lb.) is the force required to support a standard pound body against gravity, in vacuo, in the *standard locality.*

The *standard kilogram force* (1 kg.) is the force required to support a standard kilogram body against gravity, in vacuo, in the *standard locality.*

Here, by the "standard pound body" (or the "standard kilogram body") we mean one of the well-known lumps of metal which can be purchased by any one from the Bureau of Standards; and by the "standard locality" we mean any locality where g, the observed acceleration of a body falling freely from rest, in vacuo, has the standard value g_0 adopted by the International Bureau of Weights and Measures (1901), namely:

$$g_0 = 980.665 \text{ cm/sec}^2, \text{ or } 32.1740 \text{ ft/sec}^2.$$

This value g_0 is intended to be the value of g at sea-level, 45° latitude; but if subsequent measurements should ever show that the actual value of g at sea-level, 45° latitude, differs somewhat from the number here given, this number would still be retained as the definition of g_0.

The numerical relation between the standard pound force and the standard kilogram force is as follows:

1 lb. = 0.45359 kg. 1 kg. = 2.2046 lb.

Any other units of force which it may be desired, for any reason, to introduce should be defined explicitly in terms of the standard pound force or the standard kilogram force. For example:

1 ounce = 1/16 lb.; 1 poundal = 1/32.1740 lb.;
1 ton = 2,000 lb.; 1 stone = 14 lb.; 1 gram = 1/1,000 kg.;
1 dyne = 1/980.665 gram = 1/980,665. kg.; etc.

6. **The reproduction of the standard units of force in any locality.**—In order to reproduce, say, the standard pound force, it is not necessary to transport the standard pound body into the standard locality. All that is necessary is to know the value of g in the locality where one is, together with the principle that the force required to support a body in any locality is directly proportional to the value of g in that locality.

For example, suppose that an instrument maker whose laboratory is on the equator desires to construct a spring balance that shall read standard pounds force. He first determines, by pendulum observations, or otherwise, the value of g in his locality, say $g = 32.088$ ft/sec^2. Then, by the principle just stated, he knows that the force required to support a standard pound body in that locality will be 32.088/32.1740 lb., or 0.99733 lb. All that he has to do, therefore, is to graduate the scale of his spring balance in such a way that when a standard pound body is suspended on the balance in that locality, the reading shall be 0.99733. He will then have a spring balance which can be used for measuring any kind of forces, anywhere in the world, and which will always give readings in the standard pound force as the unit.

It should be especially noted that a spring balance is an instrument for measuring forces of all kinds (not merely the force of gravity), and that a spring balance once graduated to read standard pounds force will continue to give correct read-

ings in that unit in whatever locality it may be used (barring, of course, the unavoidable mechanical imperfections of the instrument).

7. **The variable weight of a body.**—Having thus established a definite, invariable unit of force, let us consider the question of the "variable weight" of a body in different localities.

The following definitions are recommended.

The *local weight* of a body, in any specified locality, is the force of gravity on that body in that locality.

The *standard weight* of a body is the force of gravity on that body in the standard locality.

Here, by the "force of gravity" on a body, we mean simply the unseen force which gives the body, when allowed to fall freely from rest, in vacuo, in the given locality, the observed acceleration g. It is equal and opposite to the force required to support the body in that locality.

Note that this definition of the "force of gravity" on a body is stated in terms of directly observable facts. The ordinary definition: "Force of gravity = the attraction of the earth," is decidedly objectionable, on account of the complications connected with the spheroidal shape of the earth, the influence of the earth's rotation, etc.*

Now it is a fact of nature that the local weight of a body varies in different localities; but this fact presents absolutely no difficulty, as soon as we have learned how to measure forces in terms of a standard unit of force. For the weight of the

* The words "from rest" used in the definition mean: "from a position which is at rest with respect to the frame of reference with regard to which the acceleration g is measured." In engineering applications, the frame of reference is, of course, always the earth; but there is no difficulty whatever in extending the concept of weight into the domain of celestial mechanics. For example, to discuss the "weight" of a body on the moon, we have merely to think of the body as suspended by a spring balance from a tripod standing on the moon's surface. From this point of view, there is no objection to speaking of the "weight of the earth itself" with respect to the sun, or with respect to the fixed stars.

body in each locality is a force, and the problem of comparing two forces is exactly as simple as the problem of comparing two lengths or two temperatures.

The relation between the local weight W_1, and the standard weight W_0, of a body is given by the principle already mentioned, namely:

$$\frac{W_1}{W_0}=\frac{g_1}{g_0},$$

where g_1 is the local value of g, and g_0 the standard value of g.

For example, if the body in question is a standard pound body, then its standard weight, W_0, will be 1 lb.; but its local weight, W_1, will be greater or less than 1 lb., according as the local value of g is greater or less than g_0.

The important thing to notice in this equation $W_1/W_0 = g_1/g_0$ is that both the forces, W_1 and W_0, must be expressed in terms of a definite common unit of force; for otherwise no comparison between the measurements would be possible.

8. The determination of the standard weight of a body.—In order to determine the standard weight of a body, it is not necessary to transport that body into the standard locality. All that is necessary is to balance the body on an *equal-arm beam balance*, against a "set of standard weights." Here by a "set of standard weights," we mean a set of metal pieces, readily obtainable from the Bureau of Standards, each of which is marked with its standard weight, that is, with the weight which it would have in the standard locality.

For example, if a given body balances a "5 lb. standard weight" in any locality, it would of course balance the same "5 lb. standard weight" in the standard locality, and hence its standard weight must be 5 lb. Certainly no relation could be simpler or more natural than this.

9. Force and motion: the fundamental equation of dynamics.—From what has been said thus far it is clear that the gravitational units of force, properly defined, are entirely adequate for the discussion of any problems involving the action of forces on a body at rest.

It remains to show that they are adequate also for the treatment of problems involving bodies in motion—problems, that is, for which the equation $F = ma$ is so often supposed to be necessary.

To show this properly, it is necessary to review, very briefly, the *fundamental principle of dynamics*, as follows.

Suppose a given body is acted on, at two different times, by two different forces, F and F_1. The effect of each force will be to give the body an acceleration in the direction of the force; and if A and A_1 are the accelerations produced by F and F_1 respectively, then the fundamental principle asserts that *these accelerations will be proportional to the forces that produce them:*

$$\frac{F}{F_1} = \frac{A}{A_1}, \text{ or } F = \frac{F_1}{A_1} A.$$

In particular, if $F_1 = W_0$, the standard weight of the body, then we know that $A_1 = g_0$, the standard value of g, and the equation becomes:

$$\frac{F}{W_0} = \frac{A}{g_0}, \text{ or } F = \frac{W_0}{g_0} A.$$

Hence we have the following important result: *If the standard weight of a body is known, we can at once compute the effect which any given force will have on that body.*

In other words, the standard weight of a body is *a measure of the inertia of the body;* for, since g_0 is a known constant, it is evident, from the equation $F = (W_0/g_0)A$, that the force F required to give the body any specified acceleration A is directly proportional to the standard weight, W_0, of the body.

This result is nothing more than the precise formulation of the commonest fact of observation concerning moving bodies, namely, that *the heavier a body is, the harder it is to set in motion;* it therefore forms the most natural possible introduction to the whole science of dynamics.

The fundamental principle here advocated is so simple, and its application so direct, that when once learned it can hardly

be forgotten. No "difficulty about units" can possibly arise if the above equation is used, since this equation involves only forces, not masses, and the ratio of two forces will remain the same, no matter what unit of force may be employed.

Moreover, if this fundamental principle is adopted, it is clear that any special discussion of the "units of mass" becomes entirely superfluous, and that the supposed advantages of the "gee-pound" or the "slugg" entirely disappear.

For, it is immaterial, for all dynamical purposes, whether a given body is described, for example, as "a *mass* of five pounds," or as having a "*standard weight* of five pounds." There is even no harm in speaking of such a body as a "five pound weight," if we understand that the term "weight," when so used, shall always refer to the *standard* weight of the body.

It thus appears—to sum up our whole discussion—that by the simple device of introducing the adjective "standard" in speaking of force and weight, we can at once secure complete scientific accuracy of statement, without sacrificing any of the convenient usages of common language.

10. **Note on the equation F = ma.**—The treatment given above contains all that is essential concerning the units of force and the effect of forces in producing motion.

Before concluding the paper, however, it seems proper to state briefly the relation between our gravitational units of force and the equation $F = ma$.

In order to bring out this relation clearly, we first call attention to the following table, which is constructed by direct application of our own fundamental equation $F/W_0 = A/g_0$.

Table I.

A Force of	Acting on a Body whose Standard Weight (or Mass) is	Will Produce an Acceleration of
1 lb.	1 lb.	32.1740 ft/sec^2.
1 gram	1 gram	980.665 cm/sec^2.
1 lb.	32.1740 lb.	1 ft/sec^2.
1 gram	980.665 gram	1 cm/sec^2.
1/32.1740 lb.	1 lb.	1 ft/sec^2.
1/980.665 gram	1 gram	1 cm/sec^2.

The first two lines of this table state facts of nature which are historically and practically so fundamental that they can hardly be forgotten; the other lines state facts which, while equally true, are of no special interest or importance, except in connection with the equation $F = ma$.

Now the constant recurrence of the numerical factor g_0 in this table is regarded by some people as an offense against the canons of mathematical elegance or convenience, and the desire is felt by such people to change the units *in such a way that the numerical factor in all three columns shall always be equal to unity.*

To satisfy this desire it is only necessary to define new units of force, mass, or length, as follows:

Force.	Mass.	Length.
1 poundal = 1/32.1740 lb.	1 "slugg" = 32.1740 lb.	1 "pseudo-foot" = 32.1740 ft.
1 dyne = 1/980.665 gram	1 "metric slugg" = 980.665 gram	1 "pseudo-centimeter" = 980.665 cm.

By the use of these units our table assumes the following supposedly more elegant or more convenient form:

TABLE II.

A force of	Acting on a Body whose Standard Weight (or Mass) is	Will Produce an Acceleration of
1 lb.	1 lb.	1 "pseudo-foot"/sec^2.
1 gram	1 gram	1 "pseudo-cm."/sec^2.
1 lb.	1 "slugg"	1 ft/sec^2.
1 gram	1 "metric slugg"	1 cm/sec^2.
1 poundal	1 lb.	1 ft/sec^2.
1 dyne	1 gram	1 cm/sec^2.

Now what connection does all this have with the equation $F = ma$? Simply this, that *the equation $F = ma$,* where F stands for force and m for mass, *is not true, unless the units employed belong to one of the systems of units exhibited in Table II* (or to some similar system); if the ordinary (gravitational) units are used, as in Table I, the equation will give *false numerical results.*

Now as a matter of fact, only one of the systems of units in Table II, namely the last, which is called the C.G.S. system, has ever come into practical use; the equation $F = ma$ is therefore useful only in the case of problems in which all the data are given in the C.G.S. system. In this special class of problems, the equation undoubtedly has a certain convenience, in as much as the factor g_0 is avoided, or at least concealed; but in any more general case, and especially for beginners, the equation $F = ma$ is exceedingly dangerous and confusing.

It may be added that no "standard weights" marked "sluggs" or "metric sluggs," and no spring balances reading in "poundals" or "dynes" (and of course no measuring tapes reading "pseudo-feet" or "pseudo-centimeters"!), have ever been put on the market.

11. **Recommendations.**—In view of the above considerations, I would propose the following specific recommendations.

1. Adopt, as the fundamental units of force, the *standard pound force* and the *standard kilogram force*, as defined in Sec. 5 ($g_0 = 980.665$ cm/sec$^2 = 32.1740$ ft/sec^2).

2. If any other units of force, such as the poundal, the ounce, the dyne, the ton, or the like, are used, let them be defined explicitly in terms of the standard pound force or the standard kilogram force.

3. Discourage the use of the *poundal* altogether, and use the *dyne* only in treating the special class of problems in which all the data are given in C.G.S. units.

4. Recognize the distinction between the *local weight* of a body and the *standard weight* of the body, as defined in Sec. 7.

5. Distinguish clearly between the two processes commonly called "weighing"; for, (*a*) "Weighing" a body on a *spring balance* gives the *local* weight of the body (in standard units of force); while (*b*) "Weighing" a body on a *beam balance* gives the *standard* weight of the body (in standard units of force).

6. Recognize the general equation $F/F_1 = A/A_1$, or $F/W_0 = A/g_0$ (see Sec. 9), as the fundamental equation of dynamics,

and do not use the special equation $F = ma$ (or $m = W/g$) except in treating the special class of problems in which all the data are given in C.G.S. units.

7. Adopt the *pound mass* and the *kilogram mass* as the only fundamental units of mass, and discourage altogether the use of such units as the "slugg" or the "gee-pound" or the "wog."

8. Whenever there is the slightest danger of confusion between the *pound mass* and the *pound force*, or between the *kilogram mass* and the *kilogram force*, write out these terms in full. (This confusion will not occur, however, if the preceding recommendations are adopted, since only forces, not masses, occur in the fundamental equation.)

If these recommendations could be generally adopted by text-book writers on elementary mechanics, the labors of both teacher and student would be materially simplified.

Discussion.

Professor E. R. Hedrick: My purpose in discussing this paper is to endeavor to give a certain point of view rather than to add any scientific information. I want to call attention to a peculiar state of mind on the part of mathematicians and engineers in regard to mathematics. Poincaré pointed out that the so-called results of the theory of probabilities have been accepted for a long time by mathematicians and scientists; by the former because they believed that there was some experimental ground for them, and by the latter because they believed there was mathematical proof for them. I think that we are likely to be in the same position regarding such subjects as are brought out in the present paper and perhaps in others which affect instruction in mathematical subjects elsewhere in engineering colleges. This condition is one justification for the getting together of mathematicians and engineers.

I suppose that engineers have thought, perhaps justly in certain cases, that such extraordinary units as the poundal and the wog, which latter is new to me, were demanded by mathe-

maticians for some obscure reason. Similarly it is probable that the mathematicians have attributed these units to some demand on the engineer's part. As a matter of fact it makes not a particle of difference whether the unit of force is called a pound or a poundal, except that a different factor must be used in certain equations. I cannot, however, see any evidence of alacrity in the adoption of these new units by the scientific and engineering world.

As I view the fundamental proposition it seems to me that the pound (or the kilogram) as recommended by Mr. Huntington should be adopted as the unit of force and I believe that this would be satisfactory to engineers. Of course, in the case of transportation of masses of matter to different localities the weights will change with the value of g, but the engineer will agree to this as necessary to maintain the validity of the equations.

Professor J. E. Boyd: The subject under discussion involves a pedagogical rather than an engineering or scientific problem. The physicists have adopted the absolute system with special prominence given to the C.G.S. units which form the basis of the units of electricity and magnetism. Physics text-books are all written from the standpoint that force equals the product of the mass by the acceleration and most books on mechanics have followed their lead.

The physicists, however, using the gram as the unit of mass, are content with the dyne as the unit of force and the erg as the unit of work. The engineers, on the other hand, want the pound as the unit of mass, and the pound force as the unit of force. This involves bringing g into the calculation at some point. After twenty-two years of experience attempting to teach dynamics to classes in physics or mechanics, I have come to the conclusion that g should be put into the formulas in the text-books in mechanics. Newton's equation then becomes

$$F \text{ (in pounds)} = \frac{Wa}{g},$$

where W is the amount of material in pounds in the everyday sense in which everyone understands it.

There has been a great deal of discussion on this subject which depends on nothing more important than the way the letters are grouped in the above formula. (1) We may say that the force is the product of the mass multiplied by the ratio of a to g. (2) We may regard the reciprocal of g as a coefficient. (3) We may call the product Wa the force in poundals which may be reduced to pounds by dividing by g. (4) We may call the quantity W/g the mass of the body. It has been our experience that it is best to give a name to this mass. We prefer the name of *gee-pound,* which, by the way, was originated by one of the members of this Society. In our classes in mechanics we have been using methods (3) and (4) together. Method (3) connects up best with the physics previously studied, and (4) fits better to the engineering work which follows. Whatever method is used we take pains to specify all the units in the equations.

We find the students have no difficulty in applying these ideas in Newton's formula, but when they come to kinetic energy, angular acceleration, etc., they sometimes forget that the formulas as usually given apply to some absolute system. To avoid this trouble and still use the formulas of the text-book, many engineers prefer to limit themselves to method (4) and say that W/g is the mass. This would solve the difficulty if it were not for the fact that the students have learned in physics that the *pound* is the unit of mass. Students have no trouble with the idea of mass until they begin to study some text-book in engineering.

Since we are practically required to teach two sets of units, I think that we would have no greater confusion than we now have if all the text-books in mechanics and engineering were written with g in the formulas, and I am sure that the busy engineer, who has forgotten some of his fundamentals, would find less trouble in using these equations in his work.

The whole matter of dynamics would have been simplified if, in planning the metric system, g had been taken as the unit of length. As this would have given an inconveniently large unit, the hour might have been divided into one hundred minutes

and the minute into one hundred seconds, which would have made the unit of length a little over four feet.

Dean C. M. Woodward: I like Professor Huntington's paper and his recommendations, except that I do not think it is necessary to discourage the use of the formaula $F = Ma$. Now what is M? Simply the ratio between two numbers W and g. You may call it by any name you choose. It simplifies formulæ to be able to represent the ratio by a single letter. The only unchanging thing about a body is the ratio, M.

The formula contained in Professor Huntington's Recommendations No. 6 is the same as that used by a man whose name I cannot recall who wrote a book on mechanics many years ago. This formula is easily comprehended by a student regardless of what name is given to M. The situation in regard to the name reminds me of a problem my father gave me in mental arithmetic when I was about six years old. He asked me "If you call a calf's tail a leg, how many legs will he have?" "Five, of course," I replied. "How absurd," said he. "He will have only four; calling his tail a leg doesn't make it a leg, does it?" People seem anxious that M should have a name. Well, give it a name, call it anything you please and use the name, but don't bother students with so much discussion about names.

Professor E. R. Maurer: The subject under discussion is an old one. The present paper is one chapter of a long controversy, as reference to the publications of this society and others will show. In the late nineties a long controversy was carried on in England in a periodical called "Nature," and about six years ago the British Association devoted a session to the teaching of elementary mechanics. The report of the proceedings of this session fills seventy octavo pages. These facts indicate many shades of opinion, and it seems almost futile to try to get together on the subject.

As I read Professor Huntington's paper I find myself in a position not radically different from that which he has taken. In my own class-work I use different methods of presenting this subject, adapting the method to the point-of-view of the

student. I have adopted certain names which are helpful to some students, perhaps not to all.

Taking up some of the recommendations in detail I would say first that in regard to the dyne, referred to in No. 2, I believe that its definition in the C.G.S. system is so generally used that no change will be acceptable. I have always used the formula set forth in No. 6 for a certain group of students who seem to take to it readily. There are other students with their instruction in physics fresh in mind who like the other better. As long as physics and applied mechanics are so closely related in college courses it is not wise for teachers of mechanics to cut loose entirely from the form of mass equations taught by the physicists. If the physicists would drop the formula $F = ma$, I could do so also.

In regard to the terms *slugg, gee-pound,* and *wog* I believe that, as long as physicists use the above formula there is use for some such expression. While I do not agree that W over g is a simple ratio, the quantities being of different nature, the students do get a better concept of the quotient if they have a name for it. A *slugg,* for example, is more tangible than W over g.

Professor G. R. Chatburn: I am pleased that this subject has been presented to us by a mathematician. I see no difficulty in mathematicians and engineers getting together on these recommendations. The trouble arises when teachers of mechanics and teachers of physics try to get together. For example, a few years ago a teacher of electrical engineering in my acquaintance told his students that they had had incorrect instruction in mechanics when their instructor had defined work for them in ft.-lb. rather than in lb.-ft. With such a point-of-view it is difficult for teachers to get together.

Now Professor Huntington would have us do away with the formula, $F = ma$, the fundamental equation of kinetics. As a matter of fact we reach the same result whether we start with Newton's law or begin with weight as the downward-pulling force and state that a weight, W, produces the acceleration g in a mass, m. We have in Newton's equation four quantities,

F, m, a and c, a constant. If we fix any three we define the fourth and can give it any name we please. From Newton's law, $F = cma$; by a proper selection of F, m and a we make $c = 1$ and the equation becomes

$$F = ma. \tag{1}$$

By considering as the weight W, that force which will give to a mass m an acceleration g, we have

$$W = mg. \tag{2}$$

This is not a general equation like (1), W and g being taken at a particular (the same) locality. Dividing (1) by (2) there results,

$$F/W = a/g, \tag{3}$$

which is Professor Huntington's equation if we say that W shall be the standard weight and g the acceleration at the standard locality. The objection to using equations (1) and (2) to obtain (3) is not well founded. This is the procedure always followed in the calculus to evaluate the constant of integration.

Professor Boyd: Most of the discussion has been in regard to mass and force. As a practical teaching proposition the third quantity, acceleration, about which we have talked little, presents the most difficulty. Students have trouble in getting a working concept of acceleration. We need more quantitative experiments in this line in mechanics.

Professor Hedrick: I want to say, in addition to my previous remarks, that I have no particular reason for supporting Professor Huntington's recommendations. I believe, however, that this society should recognize certain fundamental principles of education in this matter. We should consider not what is eventually best for research scientists to do, but what is best for the beginner in the study of this and other subjects. Personally it makes no difference to me which of the systems advocated is used. From the standpoint of adults we see that all correct systems are fundamentally equivalent. The

details which we have discussed are, to us as individuals, minor considerations.

One speaker referred to the use of the symbol *M* for *W* over *g*. Professor Huntington certainly would not object to that. Another regrets the proposal to dispense with the pound mass; but it is recommended in the paper that the pound be retained in problems dealing wholly with the F. P. S. system. The pound of mass could be retained for scientific purposes, but teaching the elements of the subject is a different matter. While to us, as I said, the details are of minor importance, we must grant that the subject presents enormous difficulties to the student. We all know from experience that the multiplicity of proposals for fundamental units produces much confusion in their minds. A sympathetic appreciation of the difficulties of students is necessary in the satisfactory solution of the present problem.

In its settlement, if there be such, I would request you to dismiss the mathematician from your minds. We wash our hands of the whole matter, and stand ready to adapt ourselves to whatever seems to you most suited to the needs of students. If the trouble is with the physicists, let that be clearly understood. At any rate let us remember that the problem is a pedagogical one.

NOTE ON UNIFORMITY OF NOTATION IN STRENGTH OF MATERIALS.

BY I. P. CHURCH,

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As regards uniformity of notation in the subject of strength of materials, first it should be said that there is already a certain amount of uniformity. Most authors use E for modulus of elasticity, I for moment of inertia of a sectional shape, P for a concentrated load, W for a distributed load and w for load per lineal unit of distributed load; and quite a large number use p for stress per unit of area. Beyond this, however, there is quite a variety of usage. (A recent text-book uses s for unit-stress and an older one the Greek σ).

To urge, in the pages of this volume, the advantages of a greater extent of uniformity in notation would only be "carrying coals to Newcastle"; but the special circumstances where in the opinion of the writer the inconvenience of non-uniformity is peculiarly felt are these: A student in a given engineering school at an early period of the course, studies a certain text-book on the mechanics of materials and gets accustomed to a special notation; including, for example, p for stress per unit area. A year or so later he finds a different symbol (say S) used for this quantity in a text-book on bridges, and in a book on concrete construction the symbol f; while in a work on masonry dams still another letter may be used for the same thing.

Whether much improvement in this respect will ever be brought about is problematical; perhaps not before Esperanto will have become the universal language; but doubtless every one in engineering circles has felt some inconvenience from the present lack of uniformity.

On the other hand, some would contend, perhaps, that so long as the notation of any one book is consistent with itself, it may not be a disadvantage if other books follow somewhat different systems; since in changing notation a student is obliged to concentrate his attention on the thing itself and not on a mere letter. In this connection it is interesting to recall that in Trautwine's "Civil Engineers' Pocket Book" many formulæ are given in which the name of each quantity is written out in so many words, without the use of any symbol.

SUMMER SURVEYING COURSES AT THE OHIO STATE UNIVERSITY.

BY C. E. SHERMAN,

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In common with a hundred other schools, we attempt at The Ohio State University to give in four years, sufficient training to our civil engineering graduates to enable them to begin practice in some such capacity as instrumentman, draftsman, designer, inspector, or computer on works of some importance. They enter with fifteen or more of the secondary school credits defined by the Carnegie Foundation for the Advancement of Teaching, and with more or less proficiency in the entrance requirements of good health, honesty, ambition, determination, and capacity to judge.

It is hard to epitomize all the traits that bring success, and one can not reduce education to a formula, but we may, as a basis for discussion, list the chief acquirements, more or less special to the engineering graduate, as follows:

1. Habits of industry.
2. Aptitude at observing things.
3. A desire to think for himself.
4. Willingness to attempt severe problems.
5. Power in attacking such problems.
6. Admiration for order and completeness.
7. An idea of how much he doesn't know.
8. Sources and methods of getting information.
9. Technical skill and information.
10. Candor.

It would be interesting to compare the attainments that are more or less special to completing courses other than in engi-

neering, but it will not be done here. The last qualification mentioned above should probably be stricken from the list. While engineering courses more patently check theories against facts, and, therefore, should more plainly teach human fallibility than do some other courses, still the quality of candor is probably chiefly congenital. It certainly is a charming trait when coupled with the second and third ones mentioned in the list.

Technical skill and information to be acquired by the engineering graduate is usually intended to include:

1. A vocabulary in engineering technology.
2. A start in the use of correct English.
3. Proficiency in drafting as a language.
4. Power in the use of mathematics.
5. Fundamentals of chemistry, physics and mechanics.
6. Principles and processes of his special subjects.
7. Cognizance of the worst mistakes often made in them.
8. Skill in using professional instruments and methods.

Also a little geology, astronomy, economics, and law, and perhaps other subjects, are usually added for mixed utility and culture.

So much for a general picture in which to set our subject. There will be differences of opinion among various instructors as to foregoing theoretical considerations, and differing degrees of emphasis will be laid upon each topic touched upon above and upon others not there listed, but engineering ideals do not vary very greatly from one college to another, and the administration of summer surveying courses will not be so much affected by the theories of instructors as by conditions existing at each school. The more obvious of these are:

1. The local topographic situation of the campus.
2. Number of students in attendance.
3. Whether only civils are required to go to camp.
4. Numbers in attendance from other courses.
5. Prerequisites for attendance.
6. Demands of the practicing profession upon the local graduates.

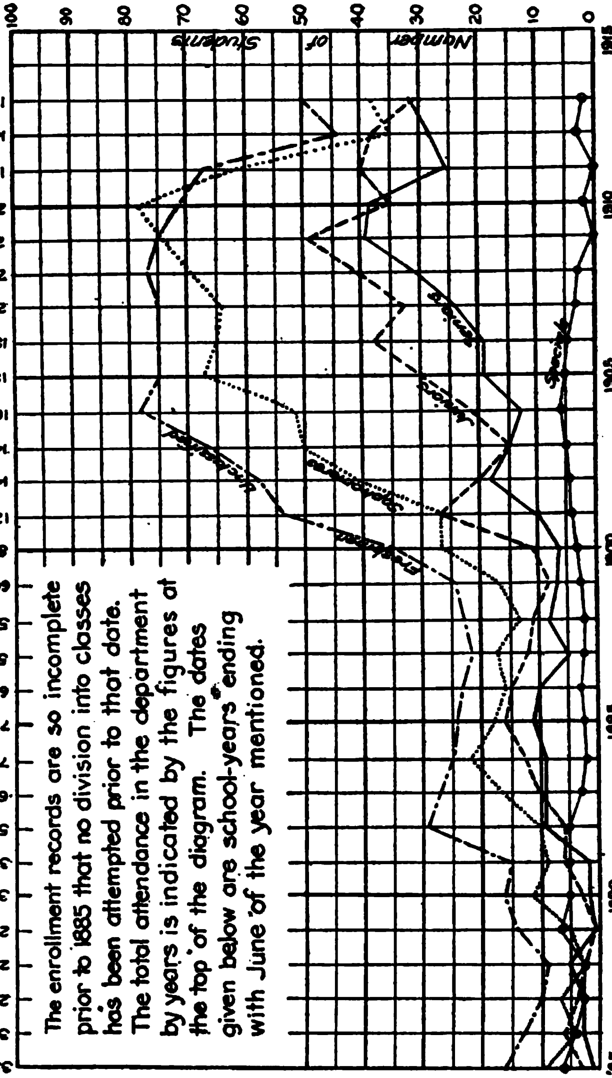

FIG. 1. Enrollment of Civil Engineering Students, The Ohio State University.

7. Local instructional facilities of the school.
8. Work covered in college outside of summer sessions.

As to local topographic situation, our engineering buildings are on a rolling campus 2,000 by 3,000 feet in size, upon which surveying exercises may be held at any time of the year. In addition, two or three hundred acres adjoining (of university land) are available for portions of the year, and a stream of 500 square miles watershed also flows through the grounds. Such topographic conditions will vary widely at different schools from the Atlantic to the Pacific.

Only some of the second and third year civil engineering students—those who do not get suitable positions on other engineering work—are required to go to summer camp. While our summer courses are open to anyone who has satisfied the prerequisites (or their equivalents) of completing the drawing of the first year and the surveying of the second, as listed later, there have been only three such students in attendance thus far. Fig. 1 accompanying shows enrollment.

Most of the demand from the practicing profession upon our graduates does not require much training in hydrographic, irrigation, or geodetic work, and these subjects have been slighted in our summer practice in the past. Geodetic work here means practical astronomy, accurate base line measurement, precise leveling and triangulation.

Local instructional facilities of a school will include such matters as: (1) Availability of state, county, or municipal public records for inspection. One of our listed land surveying exercises is abstracting from the court house records, deed descriptions of lots or tracts of land adjoining the campus. (2) Convenience of public works or grounds for use or study. For example, our juniors one fall semester finished a contour topographic survey and map of the State fair grounds; this tract of over 100 acres being almost as convenient for field practice as is the college campus. (3) The modern and extensive municipal plants of Columbus, the state experimental highways, together with many other public and corporate works, are all readily reached by street car from the class

room, and short inspection and study trips to these during the regular school year obviate the necessity for them during summer sessions.

More specifically under the last item above numbered, our state highway commissioner, during one calendar year, gave the department the task of preparing the State highway atlas. Current students working under graduates were used in executing this work, some during the regular school year, more during the summer vacation, and this reduced the summer camp attendance of that year. Again last year our new highway commissioner used one party of students under one of our instructors, in executing surveys for improvements at a distant part of the State, while another instructor used the three remaining students, who had not secured work, on surveys, plans, and estimates for a sewerage system now being installed in a nearby town.

Cornell University, it is understood, has used its civil engineering students to extend work connecting with the triangulation system of New York. Our state topographic survey will be done in three years more, and so will not be available for summer surveying purposes. Universities in other states might organize summer surveying courses to execute each season portions of such topographic surveys, or portions of road surveys to fit into systems of highway improvements planned by state highway departments. This is enough perhaps to suggest that local instructional facilities for summer surveying will vary from college to college.

The chief item affecting the administration of summer surveying courses is the amount and character of instruction given on the campus during the regular college year. This for our school is summarized in the following table of requirements for the degree of Bachelor of Civil Engineering, from which will be seen that instruction in drafting and surveying is given from the drawing of the first year to the practical astronomy of the last.

	Hours.		Hours.
Mathematics	5	Mathematics	5
Chemistry	4	Chemistry	4
Modern language	4	Modern language	4
English	2	English	2
Engineering drawing	2	Engineering drawing	2

Military drill and gymnasium throughout the year.

Mathematics	5	Mathematics	5
Physics	3	Physics	3
Engineering drawing	3	Engineering drawing	3
Land surveying	4	Railroad surveying	3
Land surveying practice	1	R. R. surveying practice	1
Topographic drawing	2	General geology	3

Military drill throughout the year.

Mechanics	5	Mechanics	5
Topographic surveying	3	Timber construction	3
Stereotomy	3	Roads and streets	3
Sanitary engineering	2	Stresses in structures	4
Electrical engineering	3	Geodesy and least squares	3
Photography	2		

Bridge design	4	Advanced bridge design or railroad economics	4
Masonry construction	3	Masonry construction	3
Water supply	3	Cement and concrete lab.	3
Geodesy and least squares	3	Contracts and specifications	2
Mechanical engineering lab.	5	Mechanism and machine design.	2
Thesis	1	Thesis	4

The figures above listed mean credit hours per week, that is, one credit hour stands for a class room exercise with two accompanying hours of preparation, or for a laboratory period of three hours duration, so that to get the actual time of "clock hours" devoted to a subject per week multiply the above figures by three, and then by eighteen weeks for the gross amount for each semester.

Explaining briefly the drafting listed above, that of the first year includes courses in projection drawing and in lettering; that of the second year, courses in descriptive geometry and in topographic drawing in which the symbols in pen and

color topography are practiced; and that of the third year applied descriptive geometry and designing in timber construction. This last subject includes lectures and text work. Work in this last subject seems to be included in summer sessions at some schools, together with a little work in masonry structures.

A brief word or two on the surveying above scheduled. In the second year, class room exercises are held in land surveying four times a week, and in railroad surveying three times a week. Both courses, more especially the latter, are used somewhat extensively to clinch freshman mathematics and drawing, in connection with elucidating the use of ordinary instruments and methods used in those kinds of surveying.

The one credit hour for field surveying in each term stands usually for exercises on the campus which are closely coordinated with the work in the class room. A party of six students under one instructor is the unit adopted for the second year surveying. A schedule of these exercises for this second year work is as follows:

Land Surveying.

Required Exercises:

1. Chaining and pacing.
2. Use of compass.
3. Use of transit.
4. Compass survey.
5. Transit survey.
6. Azimuth traverse.
7. Produce a straight line.
8. Differential leveling.
9. Profile leveling.
10. Setting grade stake.
11. Measure height of a flagpole.

Elective Exercises:

(*a*) Survey of a city lot.
(*b*) Survey a portion of the university farm.
(*c*) Measure the fall of the Olentangy river.
(*d*) Measure the grade of a sewer.
(*e*) Adjustment of the instruments.
(*f*) Court house records.
(*g*) State house records of original land surveys.

Railroad Surveying.

Required Exercises:

1. Preliminary survey.
2. Simple curve.
3. Simple curve, P. C. and P. I. obstructed.
4. A circle or semi-circle.
5. Compound curve.
6. Compound curve, P. C. C. obstructed.
7. Ladder track.
8. Slope stakes.
9. Simple curve with spirals.
10. Simple curve with spirals run continually in one direction.

Elective Exercises:

(*a*) Turnout.
(*b*) Retracing a curve on the university siding.
(*c*) Inspection trip to the railroad yards.
(*d*) Curve through several points.
(*e*) Siding to one of the university buildings.

In the fall semester each party of six juniors complete contour topographic surveys with maps of three portions of the campus or of other available ground. In size these tracts each average about three or four acres per student, and three different methods are used in surveying them. Also text assignments, lectures, and shorter campus exercises cover several other methods of topographic surveying.

In geodesy and least squares the laboratory work includes the use of the sextant, theodolite, astronomical transit, zenith telescope, and the adjustment of a quadrilateral with the necessary calculations accompanying.

It might be interjected here that we rely largely on textbooks for all our departmental courses during the college year, and require a text to be used in each course given in the department. All our instructors have been taken from the practicing profession, and no student assistants have ever been employed, with the exception of one through the present college year. Each instructor is expected to supplement the work in the class room from his practical knowledge, hence catalogs, blue prints, specifications, and so forth, are used concurrently with text assignments, quizzes, and examina-

HOURS PER WEEK DEVOTED TO SURVEYING IN CIVIL ENGINEERING COURSES.
From Catalogues for the Year 1911–12.

No.	Name of School.	Civ. Eng Attendance (Estimated) 1909–10.	Land Surveying and Topo. Drawing.		Railroad Surveying.		Topographic Surveying.		Geodetic Surveying.		Total Hours Preceding Columns.			No. Weeks 60 Clock Hrs. Each. Summer Sessions.	Grand Total of Actual Hours.
			Theory.	Practice.	Theory.	Practice.	Theory.	Practice.	Theory.	Practice.	Theory.	Practice.	Equivalent Credit Hours.		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Cornell	569	1	12	.....	.....	1	2	4	3	6	17	12	4½	1,206
2	Rensselaer	563	†135	†157	†225	†139	†150	†187	†90	†30	†600	†513	21	b 7	1,113
3	Purdue	476	9 clock		4	2	.....	8	2	2	39 clock		13	4	942
4	Illinois	435	5 credit		6 credit		4 credit		5 credit		60 clock		20	....	1,080
5	Wisconsin	363	4	6	4	6	2	5	3 credit		56 clock		19	4	1,248
6	Michigan	314	6 credit		elective		3 credit		4 credit		39 clock		13	8	1,182
7	Iowa Agr. and Mech.	308	3	18	5 credit		2	6	3 credit		63 clock		21	6	1,494
8	Pennsylvania	271	3	5½	3	1½	2	3	3	.....	11	10	14	6	1,134
9	California	247	4	4	2	6	.....	.....	2	6	8	16	13	4	960
10	Mass. Inst. Tech.	247	5	6	11 clock		2 credit		3 credit		47 clock		16	....	846
11	Princeton	244	10 clock		5 credit		4 credit		5 credit		52 clock		17	2	1,056
12	Ohio State	237	4	9	3	3	.....	9	1½	9	8½	30	20	8	1,479
13	Missouri	221	4	9	2	6	.....	15	2	.....	8	30	18	1	1,032
14	Penn. State	218	1	2	6	10	1	11	2	.....	10	23	18	....	954
15	Ohio Northern a	211	a 5 credit		a 5 credit		a 2½ credit		a 5 credit		a 52½ clock		a 17½	9	1,170
16	Mich. Agr. College a	200	a 4	a 8	a 3	a 5	a 3	a 4	a 1	a 4	a 11	a 21	a 18	....	648
17	Lehigh	187	†116	†54	†80	†108	†70	†110	†120	†56	†386	†328	15	8	1,194
18	Texas Agr. and Mech.	185	3	4	5	7	.....	.....	3 credit		44 clock		15	....	792
19	Maine	184	2	7	2	2	1	.....	.....	.....	5	9	8	2	552
20	Kansas	180	5	11	5	5	.....	.....	.....	.....	10	16	15	8	1,308

21	Stanford	178	2	9	2	9	.....	.....	.....	.....	4	18	10	.....	540
22	Yale *a*	177	.....	*a* 7	*a* 3	.....	.....	.....	*a* 3	*a* 6	*a* 6	*a* 13	*a* 10	7	792
23	Nebraska	177	2	5	1	6	2	5	.....	.....	5	16	10	.....	558
24	New York	176	4	10	2	.....	2	.....	1	.....	9	10	12	8	1,146
25	Minnesota	155	.....	4½	.....	.....	.....	4½	2	.....	2	9	5	.....	270
26	Brown	152	4	12	3	6	1	.....	1	2	9	20	16	.....	846
27	Univ. of Wash.	150	4	9	3 credit		3	.....	6	.....	57 clock		19	.....	1,026
28	Washington and Lee	148	6	5	.....	.....	.....	.....	3	.....	9	5	11	.....	576
29	Norwich	146	2	4	3	.....	2	.....	2	2	9	6	11	10	1,194
30	Columbia	143	2	.....	5	6	.....	.....	.....	.....	7	6	9	16	1,446
31	Syracuse	137	6	10	3 credit		.....	.....	7 credit		54 clock		18	6	1,332
32	Armour	135	6	6	3	.....	3	.....	3	.....	15	6	17	.....	918
33	Valparaiso *a*	124	*a* 5	*a* 10	*a* 6	*a* 14	.....	*a* 12	*a* 5	.....	*a* 16	*a* 36	*a* 28	.....	1,008
34	Brooklyn Poly.	122	16 clock		8 clock		4 clock		2 credit		34 clock		11	.....	612
35	Oregon Agr. Col.	116	2	7	3	6	1	8	.....	.....	6	21	13	.....	702
36	Univ. of Texas	113	6	6	3	3	.....	3	3 credit		54 clock		18	.....	972
37	Univ. of Colorado	109	3	3	3	9	3	3	2 credit		48 clock		16	.....	864
38	Virginia Poly. *a*	100	*a* 3 credit		*a* 3 credit		*a* 9	*a* 27	*a* 3	.....	*a* 81 clock		*a* 27	.....	972
39	Tufts College	99	3	.....	3	.....	.....	.....	.....	6	6	6	8	3	612
40	Case School	98	5	5	4	10	.....	.....	4	.....	13	15	18	12	1,692
41	Iowa State Univ.	94	2	9	5 credit		2	6	3	.....	51 clock		17	6	1,278
42	Georgia School Tech.	94	1	3	3	4	3	4	3	2	10	13	14	.....	774
43	Lafayette *a*	89	*a* 4	.....	*a* 7	.....	*a* 2	.....	*a* 4	.....	*a* 17 credit		*a* 17	6	972
44	Delaware College	87	4	6	8 clock		4	8	.....	.....	46 clock		15	.....	828
45	Cornell College	85	3 credit		3 credit		3 credit		.....	.....	27 clock		9	.....	486
46	Kentucky State *a*	84	*a* 4 credit		*a* 1 credit		*a* 13 clock		*a* 4	.....	*a* 40 clock		*a* 13	.....	480
47	Wash. State Col.	81	2	6	2	6	1	6	7	6	12	24	20	.....	1,080
48	Worcester Poly.	80	12 clock		10 clock		4 clock		15 clock		41 clock		14	9	1,278
49	Kansas Agr. *a*	79	*a* 2	*a* 10	*a* 3	*a* 8	*a* 1	*a* 4	*a* 2	*a* 4	*a* 8	*a* 26	*a* 17	.....	600
50	North Carolina A. and M.	77	*a* 2	*a* 6	*a* 4	*a* 6	.....	*a* 4	*a* 4	.....	*a* 10	*a* 16	*a* 15	.....	552
51	Union *a*	74	*a* 4 credit		*a* 5 credit		*a* 5 credit		*a* 6	.....	*a* 60 clock		*a* 20	7½	1,170
52	Alabama Poly. *a*	67	*a* 2	*a* 2	*a* 5	*a* 6	.....	.....	.....	.....	*a* 7	*a* 8	*a* 10	8	828
53	Univ. of Oregon	65	2	12	.....	.....	1	6	.....	3	3	21	10	.....	540

No.	Name of School.	Civ. Eng. Attendance (Estimated) 1909–10.	Land Surveying and Topo. Drawing.		Railroad Surveying.		Topographic Surveying.		Geodetic Surveying.		Total Hours Preceding Columns.			No. Weeks 60 Clock Hrs. Each. Summer Sessions.	Grand Total of Actual Hours.
			Theory.	Practice.	Theory.	Practice.	Theory.	Practice.	Theory.	Practice.	Theory.	Practice.	Equivalent Credit Hours.		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
54	Washington, St. Louis......	65	2	3	1	6	3	.....	.....	6	6	15	11	6	954
55	Geo. Washington..........	63	2	3	4	6	2	3	1	3	9	15	14	....	756
56	Univ. of Arkansas.........	62	3	6	4	8	.....	3	.....	.....	7	17	13	1	744
57	Vermont..................	61	3	1	6	.....	6	.....	4	.....	19	1	19	12	1,764
58	Rose Poly.................	60	1	9	.....	21	.....	9	.....	.....	1	39	14	4	996
59	Clarkson *a*...............	59	*a* ½	*a* 1½	*a* 1½	*a* 1½	*a* ½	*a* 1½	*a* ½	*a* 1½	*a* 4*c*	*a* 7*c*	*a* 11	*b* 2	396
60	Miss. Agr. and Mech. *a*.....	56	*a* 5	*a* 9	*a* 5	*a* 9	*a* 2	*a* 14	.....	.....	*a* 12	*a* 32	*a* 23	....	816
61	Vanderbilt................	54	4	12	2	3	2	3	6	.....	14	18	20	....	1,080
62	Maryland Agr. Col.........	54	*a* 2	*a* 12	*a* 6	*a* 4	*a* 8	*a* 8	.....	.....	*a* 16	*a* 24	*a* 24	....	864
63	Penna. Military...........	54	*a* 10 clock		*a* 26 clock		*a* 10 clock		.....	.....	*a* 46 clock		......	....	598
64	West Virginia *a*..........	53	*a* 3 credit		*a* 3 credit		*a* 3 credit		.....	.....	*a* 27 clock		*a* 9	....	324
65	Clemson..................	52	4	4	9	9	.....	.....	.....	.....	13	13	17	....	936
66	Colorado Agr. Col..........	52	2 credit		7 clock		2 credit		2	3	28 clock		9	....	504
67	Univ. of Cincinnati........	51	.....	.....	3 credit		.....	.....	.....	.....	9 clock		3	Time not given	....
68	Univ. of Virginia *a*.........	51	*a* 3	*a* 9	*a* 3	*a* 9	.....	.....	.....	.....	*a* 6	*a* 18	*a* 12	....	432
69	Thayer....................	50	†204*d*		†45*d*	†140*d*	†345*d*		†24*d*	†20*d*	†1020*d*		......	....	1,020*d*

Notes on Above Table.—"*c*" includes a course in highway surveying. "*a*" means twelve-week term; all other figures are for 18-week term. "*d*" represents maximum time devoted to subject by average student. † means total clock hours devoted to subject. "*b*". Is time included in practice hours of preceding columns. Figures in the columns marked "theory" mean credit hours per week, and have been multiplied by three to get the total actual time demanded of the student. Figures in the columns marked "practice" mean the actual hours per week devoted to that feature of the subject. Figures on the lines between theory and practice columns mean that theory and practice are not subdivided in the catalog.

tions, as is largely the practice at all other engineering schools.

Such a lengthy statement, as the foregoing, of the work done on the campus at each school, would have to be given to understand rightly the work of its summer sessions. The following table, extracted from catalogs for the year 1911–12, exhibits the work in drafting and surveying required at the larger engineering schools in the country. These schools have been listed in the order of their numerical attendance in the year 1909–10, which seems to have been a high water mark in engineering. College catalogs in general seem to be unreasonably obscure, when used to get tables such as the one here attempted. Considerable correspondence was necessary to supplement the information catalogued, and the table is undoubtedly slightly in error at places.

Inception of Summer Surveying Courses.

In response to student sentiment, and in view of the fact that the campus exercises gave no noticeable proficiency in the use of instruments, nor an adequate idea of procedure in the field, a special course in field practice was tried in June, 1888.

The class of seven second year civils in charge of Professor Brown, after studying land and railroad surveying for a year, spent one week in June in making a reconnoissance, preliminary, and location survey for a proposed electric railway two and a half miles long, between two small towns distant about 60 miles from the University in the rough southeastern portion of Ohio. Most of the field work was completed, map drawn up in pencil, and earthwork partly figured before leaving the field. The party boarded at a hotel during the session.

This first piece of near-practical work, together with the prejudice against college men that then existed among practicing surveyors, aroused a desire in succeeding classes to supplement their exercises on the campus with such summer work, and in response to the growing sentiment among students and instructors, in the year 1900 the University authorities, for the first time, furnished the necessary funds to purchase a com-

plete camp outfit, and to hold a summer session of four weeks duration. Simultaneously the requirement of attendance at two of these sessions, each of four weeks, one for the sophomores at the end of the second year, and one for the juniors at the end of the third year of the course, was added to the other requirements for a degree. The department from the outset has reserved the privilege of accepting suitable equivalents for attendance at these two summer camps or sessions. That requirement and power of substitution has been in force down to the present time.

Practice Summer Camps.

The first three encampments of 1900, 1901, and 1902, were planned and executed amid circumstances and with results so nearly alike, that all three can be readily described under the caption used above.

The bituminous coal region of western Pennsylvania, West Virginia and southeastern Ohio forms one of the choppiest extended areas in the United States. The land is poor for agriculture, and its owners, and the coal mining companies owning mineral rights therein—frequently owning large tracts outright—have little objection to running lines or cutting small timber in any direction that surveys may be projected. Consequently this region affords excellent sites for practice, and the first three camps were located on large tracts of land owned by coal companies in this region.

The steep and wooded or brushy hillsides upon which to fit curves afforded an excellent opportunity to show the advantages of paper location, and of other surveying methods and difficulties which could not be well shown on the comparatively flat college campus where the grass was kept trimmed most of the time.

While different localities were selected each year, camp was established in each case about three or four miles from the nearest small town, and the discipline of a regular surveying party maintained. To infuse order and system at the outset,

for the first two weeks the whole camp was organized into a railroad surveying corps, and possible railway projects were examined with the methods, care and speed of professionals, as nearly as might be, with the one exception that each day the men were rotated in position according to a predetermined schedule.

PRACTICE SESSIONS.

Year.	Total Department Enrollment.		Comp. Attendance.			Place.	Miles from University to Camp by		Character of Work.	Fee Charged to Each Student.	Rebate to Each Student.	(?) Net Cost to Each Student.
	Soph.	Junior.	Soph.	Junior.	Instr.		Rail.	Wagon.				
1900	29	13	10	4	2	Nelsonville, O.	62	3½	Railroad,	$20.00	$2.75	$17.25
1901	30	24	10	6	3	Creola, O.	70	2	Land and	20.00	2.60	17.40
1902	49	26	11	4	3	Corning, O.	64	4	Topographic	20.00	1.92	18.08

AMOUNT OF WORK DONE DURING THE FIRST TWO WEEKS IN RAILROAD SURVEYING.

Year.	Miles of Reconnoissance.	Miles of Transit Line.		Miles of Levels.		Miles of Topography.		Cross Sectioning.	Computing.	Drafting.
		Preliminary.	Location.	Preliminary.	Location.	Taken in Field.	Mapped in Office.			
1900	*12	9.2	3.7	9.2	3.7	*4.0	*4.0	Practice work in		
1901	*10	7.8	3.8	7.8	3.8	3.8	3.8	these given to		
1902	* 5	*9.3	*2.5	*9.3	*2.5	*3.0	*2.5	each student		

The work accomplished during the first half of these sessions is exhibited in the above table, and the character of the country may be judged by the map† and photographs accompanying. The lines were arranged in closing circuits, closure errors calculated, and all directions referred to the true meridian by observations on Polaris. All hands joined in the reconnoissance made with pedometer, barometer, pris-

* Estimated.

† See U. S. Geological Survey maps.

1900, Nelsonville, O.

1902, Corning, O.

1903, Homeward bound, up Kingdom Come.

1903, Whitesburg, Ky. Under the Persimmons.

matic compass, and such maps as could be had, only very poor ones being then obtainable.

Each student took turn at cross-sectioning, computing earthwork, and plotting. Paper location notes were scaled, after the topography had been inked, and were checked on the preliminary lines in the field. Levels were kept up with transit lines and both plotted to date at night. All hands helped on the drafting, the most proficient usually doing the finishing. Rotation in position, roughness of the country, and patches of woods and brush were the greatest drawbacks to progress.

Both sophomores and juniors, who had not obtained work elsewhere, were engaged on the above surveys without much distinction as to rank, except that juniors were assigned to the more responsible positions at the outset, so as to strike a good pace in accuracy and speed. Office work was done each night, plotting notes, inking maps, and calculating earthwork. Rainy days were also used on such work.

After the close of the first two weeks, the juniors made a stadia topographic survey of as large a tract as they could, and the sophomores engaged in surveying farm boundaries. Since many farm corners were witnessed to by existing or former trees, the identification of the various species of hardwood became important. This region of the country is the home of nearly fifty kinds of hardwood, and their identification was made a valuable adjunct to other camp instruction. This practice of identifying trees at summer sessions has been kept up wherever feasible. The student gets his start in such work in our campus exercises where the trees on the grounds form an extensive arboretum.

The assignment of a student to one position for a whole day or two was a big improvement over the campus exercises where the assignments averaged not more than three hours to a position. Camp work gave a much better idea, than did campus exercises alone, of the difficulties encountered in practice, of the organization of parties for regular surveying work, of the management of such parties in the field and office, and of the amount that should be accomplished in a day by the

commoner methods that had been dwelt upon in class room. It made the boys better acquainted with each other and the instructor, and emphasized to them that there are qualities that make for success or failure, that are not brought out in the class room. It furnished a healthy outing, taught a little sanitation and hygiene useful to them in similar situations in the future, taught a little dendrology, and made the teaching in the class room through the following year a little more real.

These advantages seemed so good at first that we questioned whether we should excuse any of the students from attending camp to accept practical work, as we had been doing from the beginning. However, it was noticeable that the boys who had been excused to go on engineering work during the summer came back with fine spirit to their tasks the following fall. So after the first three sessions, there being only nine students left to go to camp, in 1903, and practical work offering at fair compensation, it was accepted and these students used in prosecuting that work.

We were so pleased with this change in our system at the close of 1903, that we have been following the plan ever since. We have continued to allow students to substitute engineering employment for attendance at camp and every year since have been fortunate enough to contract for work on which to use the boys who did not get summer employment.

Those offering substitutes are required to get suitable experience, including instrumental and office work, and credit for such summer work has thus far always been withheld until just before graduation, in order to spur the student on to his best endeavors and in order to give each one the widest opportunity to secure suitable employment.

This last is determined by requiring each one to file during the fall semester a statement of the work he did, giving among other details the addresses of his employers. Blank certificates are sent to these employers, and when returned they are used in connection with the statement of the student,—with any additional facts in possession of the department—to determine the amount of credit to be given. The blank form,

with but insignificant change, has been in use since 1900. These certificates, signed by the employers and covering the equivalents of both summer sessions, must be on file in the department, before a degree is awarded.

COPY OF BLANK SENT TO EMPLOYER.

THE OHIO STATE UNIVERSITY
DEPARTMENT OF
CIVIL ENGINEERING
Columbus, O.,..............................

....

....

....

Dear Sir:

The work that Mr. .... has done under your direction may entitle him to credit for certain of our required studies. To determine this will you kindly fill out the following blank with ink and return to me at your earliest convenience. Your answer on this blank is filed as the official evidence for giving credit, when such is obtained.

All of the information given by you is for the private use of the instructors of the Department of Civil Engineering and will not be made public without your permission.

Very respectfully yours,

....

When did Mr. .... enter your service?..........

How long did he work under your direction?..........................

How long did he serve in each of the following positions?

Transitman .... Levelman ....

Topographer .... Draftsman ....

Rodman .... Chainman ....

Office Work ....

....

Was his work satisfactory? ....

Would you re-employ him if needing help? ....

Do you think him "cut out" for an engineer? ....

Give a brief description of his work with you which is not covered by the foregoing questions.

Give any other information which you think will help us in forming a true estimate of the man and his work.

....

....

....

....

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Signed ....

Date ....

Address ....

....

Practical Summer Camps.

What we may for brevity term here the practical camp system means the practice of accepting suitable contracts for surveying, using for this purpose the students who do not get positions for themselves. Under this system the accompanying table shows what has been accomplished during the past ten years. The table is expanded, for those who wish more detail, into the following brief accounts of the sessions of each year.

1903.

An Indianapolis syndicate agreeing to pay us $450 for each of two parties of six, for four weeks of surveying in southeastern Kentucky, with the option of employing the students longer, we spent the month tracing boundaries of private lands with a view to adjusting titles and determining the extent of each claim.

Our tents were pitched on the north fork of the Kentucky River about two miles below the mouth of Kingdom Come Creek, celebrated in that charming story, *The Little Shepherd of Kingdom Come.* We traveled 446 miles by rail, and then by mountain road and trail for two days more to reach

PRACTICAL SESSIONS.

Year.	Total Department Enrollment.		Camp Attendance.			Place.	Miles from University to Camp by		Character of Work.	Fee Charged to Each Student.	Average Rebate to Each Student.	Net Cost to Each Student.
	Soph.	Junior.	Soph.	Junior.	Instr.		Rail.	Wagon.				
1903	40	17	8	1	3	Whitesburg, Ky.	446	40	Land	$20.00	$20.00	$ 0.00
1904	40	25	No summer session held by any department of the University									
1905	53	32	26	6	4	Yellowstone Park	1836	5 to 30	Topographic	56.00	0.00	56.00
1906	48	39	13	0	2	Willoughby, O.	155	0	Street and sewer	26.00	10.30	15.70
1907	50	33	11	0	2	Willoughby, O.	155	0	Street and railroad	26.00	11.25	14.75
1908	62	36	10	0	2	Mentor, O.	159	2	Land and topographic	26.00	2.76	23.24
			0	8	2	Ft. Ancient, O.	73	1	Topographic			
1909	59	36	13	1	2	Buckeye Lake, O.	38	3 to 5	Land	26.00	15.33	10.67
1910	45	33	9	2	3	Wellston, O.	86	2	Railroad	26.00	21.04	4.66
1911	55	34	12	2	3	Minster, O.	110	4	Land	26.00	20.00	6.00
1912	40	32	4	2	2	Columbus, O.	0	0	City and topographic	6.00	16.00	* −10.00
						Ironton, O.	127	0	Highway			

* In 1912 only the $6 University fee was collected from each student, each one paying his own living expenses in Columbus.

the site. Owing to the distance traveled, camp furniture was reduced to a minimum, camp beds being made out of boughs.

The situation was a novelty for us all. The peculiarities of the deed descriptions, the steepness of the hillsides, and the overlapping of the land lines made a particularly trying task. The land lines in this region are doubtless more confused than in any other part of the United States. As many as five claims, deeds, or patents cover identical parcels of ground at places in this portion of Kentucky, and to make matters worse the deeds are often very badly written. Several were as bad as the following which is copied from official records:

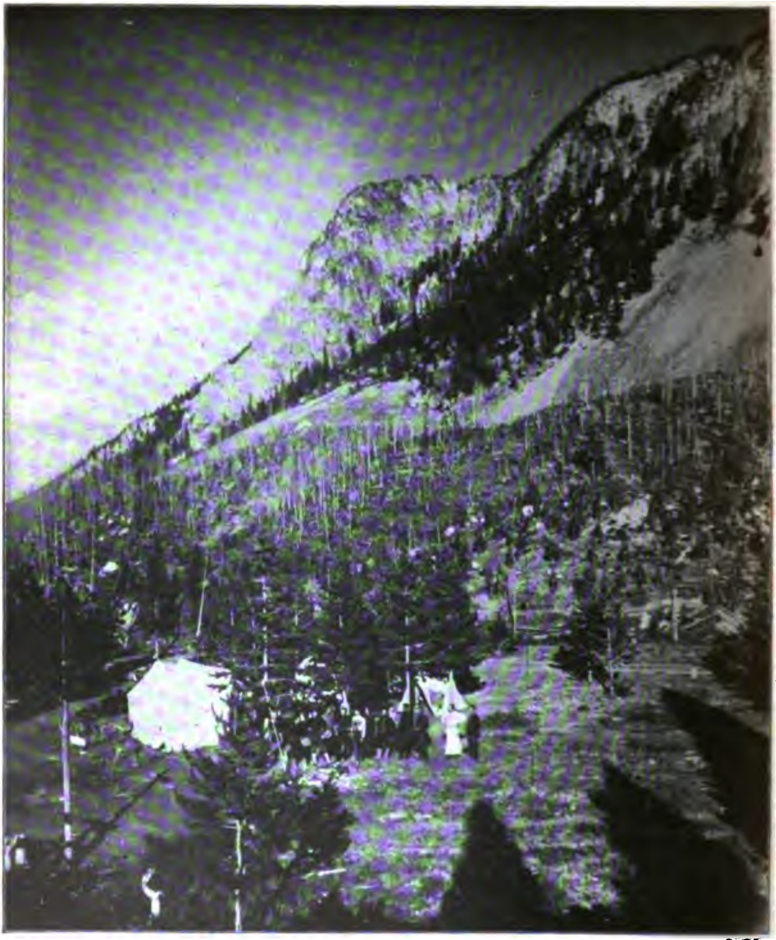
> Beginning at the road at the School House lot, thence with the road to the ford of the run above the mill, thence back in the field about 6 rods to or near a small black walnut, thence to or just above the white walnuts at the spring in the drain, thence just above and with the meanderings of the fence, now around the upper side of lot, to a small sugar tree by the old fence going up the cliff, thence with the creek to the branch below the ford to P. Hammack's line and with his line to W. R. T. Smith's corner.

There were only nine students camping and we hired a local axman to fill out the quota, an instructor being in charge of each party. About 2,000 acres, made up of varying sized tracts, were surveyed by the end of the month, and our progress satisfied our employers; but we were under-bid by local surveyors when it came to continuing the work.

A description of the methods of surveying as affected by the local situation would too much extend this article. The quaint customs and language of the people of this region and the happenings in camp, form the basis of an article written for the *University Monthly,* under title "A Journey to the Land of Kingdom Come."

1904.

The university being without funds for the purpose, no Summer Session was held by any department this year, and the requirement was accordingly waived.



1905, Yellowstone Park.

1905, Yellowstone Park.

1905.

We secured the ideal work of making contour topographic maps of stage roads in Yellowstone Park for this session, our compensation consisting of transportation and subsistence while prosecuting the work and at its close a one week touring trip around the Park. This session consumed six weeks, one week coming and going, four weeks on the work, and one week touring the portions of the Park that each party had not seen. The regular camp fee has always been $20, which covers railroad fare to and from camp, together with subsistence for four weeks of the regular session. In this case, however, the students voted to pay a fee of $56, which was necessary to cover expenses from the university to the Park and back, the university trustees in this instance remitting the six dollar fee for the instruction of the summer term.

The United States Engineer Office at Mammoth Hot Springs furnished all camp equipment. The thirty-two students were divided into three parties, each under an instructor as chief, with an additional instructor in general charge having headquarters at the Springs. One party surveyed from Gardiner toward Norris Geyser Basin; one from Norris to Grand Canyon; and the third from Mammoth Hot Springs toward Tower Falls.

In all, forty-two miles of roads were surveyed, and mapped to a 200-foot scale, in the four weeks of work, showing the topography closely by contours for 200 feet on either side the transit line, and 400 or 500 feet further by approximate methods. The object of the survey was to furnish maps and profiles for administration purposes, and to show the features of interest to the tourist along each route.

The work was specially organized to accomplish these purposes. A transit line was run along the road by deflection angles checked every ten miles on the Pole star, with distances measured twice and levels doubly run. One party took no topography but that of the immediate road and structures, one only the side notes from the road out 200 feet, and the third with the stadia took the outlying strips.

A special code of topographic symbols was necessary to represent the features on these maps. The variety of natural topographic features in this region is doubtless unequalled in any other equally sized area in the world. All hands assisted in drafting on the field maps at nights and on rainy days, and, during the school year following, these maps were traced in color on atlas sheets 18×28 inches. The students were paid for the latter work, which was done mostly during the Christmas vacation following the summer in the Park. A reprint of the symbols used, together with an excellent map of the Park, was given in a commemorative bulletin of the department published in August, 1910.

Needless to say the work of this session was most instructive and engaging. Special cars for the party were chartered to and from the Park, and the memories of the trip will always linger in the minds of those who made it. The social side of this unusual summer session has been described in an article in the *University Alumni Quarterly* for April, 1911, for those who may wish information on this feature of camp work.

It was the intention, after systematic road surveys had been started, to continue the work for several summers to completion, exhibiting the results in ten atlases. Only three atlases, not reproduced here, were completed at the 1905 session, and before plans were inaugurated for the subsequent summers, the administration of the road system in the Park was transferred to the cavalry branch of the army instead of continuing it under the corps of engineers. General H. M. Chittenden, now president of the Port commission of Seattle, was the engineer officer, in charge at the time of the survey, who so kindly gave us the opportunity of doing the work.

1906.

Thirteen students and two instructors pitched camp in an orchard in the center of Willoughby, Ohio, about twenty miles east of Cleveland. Board was obtained at a local restaurant. Profiles were made of all the streets for the use of the county surveyor who was employed by the village to establish street

and sidewalk grades, and for the use of the campers in designing a sewer system. The village hall was used for an office and drafting room for this camp as well as that of the following year, as shown in the photographs accompanying. The boys were rotated in their positions on the parties every third or fourth day.

The village voted the necessary bonds for the sewer system and one of the students, remaining out of school for a year, acted as resident engineer in the installation of the system, while one of the instructors acted as chief engineer for the village. Two of the students in this camp were instructors in other institutions.

1907.

Eleven students under two instructors this year, camping on the site used the previous year, completed inventory surveys of eight miles of electric railway, and surveys for improvement of five miles of adjoining highway. The railway maps were finished in atlas form exhibiting rail, pole, wire, siding, and other construction in detail by a code of special symbols. The highway maps were made up in the standard form prescribed by the State for state aid roads, on sheets 18 by 36 inches showing alignment, profile, cross-sections, and adjoining property features.

It was interesting to the students to find their transit lines checking with each other, and with the work of the previous year, within one minute, all tied on to the true meridian by their own observations. This work was all done for the county surveyor of Lake County, who paid a small sum to each student and a contribution toward reducing the expense of administering the camp.

1908.

Two suitable tasks being available when the time arrived for camp, the students this year were divided, the juniors going to Fort Ancient in southwestern Ohio and the sophomores to Mentor in the northeastern part of the state. The latter students surveyed the 1,008-acre farm of Mr. L. E.

Residence
Terraces
Randall
Run
LEBANON
CHILLICOTHE
PIKE
Hedge
Hedge
750
750
800
800
850
850
890
890
916
920
924
926
928
930
932
934
914
Barns
Residence
Pavement
Pavement
Old Hotel Site
N E W
F O R T
DRIVEWAY
Stone Mound
Stone Circles
R. M.

Holden, president of the *Cleveland Plain Dealer*. In addition, the class also made a detailed contour topographic survey, for the purpose of landscape gardening, of about 20 acres immediately surrounding the mansion and its accessories. The survey of the larger tract included determining the boundaries, subdividing into lots of approximately forty acres, locating lines of tiling, setting elevations with wye level, and locating the other important features within the tract. Maps of both surveys were also completed as a part of the work, the maps being finished after the closing of camp.

Fort Ancient is one of the two greatest prehistoric earthworks of the country, the other being Cahokia Mound in Illinois. This classic ground, located in Warren County about 80 miles from Columbus, is the property of the Ohio Archæological and Historical Society and they had but $120 to apply toward the work of surveying, other funds being needed for archæological explorations, which were carried on during the time that the surveying was being done. On this trip the surveyors and the archæologists, or "peg-whackers and "grave-robbers" as they good-humoredly dubbed each other in recreative contests, used a common camp.

Within the four-week session the eight juniors under two instructors (one of them necessarily absent a portion of the time) completed in pencil a map 5 by 10 feet in size to a scale of 50 feet per inch, showing all the surface features including the relief. Some of the slopes were heavily wooded or quite brushy.

The original map, now in the archives of the Society, was finished in four colors. The comparatively flat top is shown by two-foot contour intervals, and the steeper and usually wooded slopes, outside the breast-works, were represented by contours ten feet vertically apart. A little more than three miles of transit base line was run around the top from which accurate cross-sections gave the breast-works very closely. Eleven miles more of transit base line, as many miles of levels, and stadia-taken topography made excellent practice for the

students. Stadia notes were reduced by slide rule at the close of each day. All work was referred to the true meridian, as is our usual practice, by observations on Polaris or the sun. The map was finished after the close of camp, by one of the students working under an instructor, and turned over to the Society.

For the work at Mentor the contract price was $275, and for that at Fort Ancient $120. With only these small sums the work was completed very satisfactorily at both places, and rebates were made to each of the eighteen students. These two surveys were interesting instances of work that would not have been done at all if private surveyors only had been available.

1909.

Fourteen students and two instructors surveyed the south shore of Buckeye Lake, one of the canal feeder reservoirs in Licking, Fairfield and Perry Counties, for the Board of Public Works of the State of Ohio. Camp was established first at the east end of the lake and later near the west end as the work progressed. The lake is about seven miles long. One of the instructors at this camp was the chief engineer for a coal company, who in his official capacity had had considerable experience in land surveys, and who took the task during his vacation.

The State Board of Public Works had no adequate survey of the south shore of this lake and this made an ideal problem for the summer course. In doing the work, the parties were organized as follows:

1. A level party, which placed stakes in sets of three, first a lath stake on the present shore line, second, a lath stake on the standard water level as determined by the mark on the north outlet lock, third, a $\frac{3}{4}'' \times 1\frac{1}{2}'' \times 18''$ stake, painted white, 12.12 ft. measured outward from the standard water level stake, this being the line claimed by the state as its line of ownership. These sets of stakes were numbered consecutively from the beginning so as to insure none being missed by the following parties.

2. A transit party which ran a line as near as feasible to the stakes set by the level party. This line was run by setting lath stakes every station, angles were doubled and magnetic bearings read. Azimuth was determined by observations on Polaris. The points where the legal subdivision lines crossed this line were monumented by setting a 4″ tile, 2 ft. long, filled with concrete. The angle point on each side was monumented by placing a 4″ tile, 1 ft. long, 1 ft. under ground. This transit line was 17.5 miles long.

3. A topographic party, which located the stakes set by the level party by tying them to the transit line by right angle offsets. They also located buildings, fences and other prominent features near the line.

4. A land party, which ran all the legal subdivision line and the principal property lines adjacent to the lake. These lines were tied to the main transit line along the shore of the lake.

The work of the regular transit party and land tie party made closed surveys which were figured for error of closure. The worst of these closures was 1 in 4,000, the average being 1 in about 8,000. The calculating and most of the field plotting was done in the office tent at camp in the evenings. Five of the students were retained after the close of camp for from one to three weeks to complete the final plotting, which was done at the university.

At this camp the expedient was tried for the first time of keeping the boys at the position until a rotation would not hinder the progress of the work. This was found to be better than uniform rotation so that it has been continued on all the following summer courses. The penciled maps were delivered to the State Department and now constitute a part of its official records.

1910.

Eleven students and three instructors made relocation surveys 9½ miles for an existing railway near Wellston, Ohio, in Vinton and Jackson counties. The company was considering reconstructing part of their line, and had surveying parties in the field but for this one particular section there

were several possible routes which required investigation. The company was glad to use the students on this work, and they accomplished very satisfactory results.

All of the field work and most of the plotting was completed in the four weeks, at which time camp was broken, the plotting and calculating being finished at the university. Not being satisfied with the field drafting, the maps were retraced at the university on detail paper, using a home made electric light tracing frame. These finished maps are in possession of the railroad company.

The profiles, cross sections, estimates, and all, made an ideal task for the students, because it was in a rough country, and only first class construction, grades, and curvature, were contemplated on the new line.

1911.

The work of 1911 was similar to that of 1909. Fourteen students and three instructors camping near Minster, Ohio, surveyed the state land adjacent to Loramie Reservoir in Auglaize and Shelby counties, for the State Board of Public Works.

The work was organized in a similar manner to the Buckeye Lake survey, excepting that the transit party did no linear measuring, but set stakes on the transit line where the perpendiculars from the contour stakes would strike their line, and that the topographic party did all the linear measuring. Every transit point was monumented with a cast iron monument, requiring the setting of in all about 400 monuments. The main transit line was 34.6 miles long.

The maps for this survey were largely drawn and inked in the field, an extra draftsman being employed to insure uniformity in the finishing of the maps. They were drawn in atlas form on a scale of 300 feet per inch, and constitute a part of the State's official records.

1912.

During the summer of 1912 no camp was established. Six students were organized into two parties, each under an instructor. Various surveying jobs were obtained and kept the two parties busy for the regular four weeks, after which the six students secured other positions.

The work done was closely as follows: (1) Made surveys, designed, and drew plans for about 5 miles of sewers for a village adjacent to Columbus. (2) Made surveys and plans for the State Highway Department of about $1\frac{3}{4}$ miles of "state aid" road in Lawrence county. (3) Made land and topographic surveys of 20 acres of land recently purchased by the university. (4) Set all stakes necessary for a building being constructed on the campus. (5) Set stakes for a heating tunnel being constructed on the campus. (6) Located two city lots for private owners.

General Remarks on all Foregoing Sessions.

Our regular department year, coinciding with that of the college and university, has, since the opening of the institution in 1873, lasted on the average from the middle of September to the middle of June. All our summer surveying sessions, omitting from discussion that of 1888, have begun on the Friday preceding commencement and lasted four weeks, with the exception of that in 1905, which lasted six weeks.

A regular camping outfit of tents and accessories has always been used, excepting last year. Regular camp cooks have generally been employed, excepting last year, and at the Willoughby camps.

With plenty of good wholesome food furnished, the expense in camp has never exceeded $20 per student. Railroad fare has increased the cost over this amount in three instances, but in two of them the rebate out of funds paid for surveys made the net total cost to each student less than that fee, so that $20 has always been charged to cover camp expenses, except in the case of Yellowstone Park. Since 1905 the uni-

versity has also added a summer session fee of $6.00, upon which no rebate has been made.

As to discipline, the amount of work accomplished has kept the boys so busy that they have had no time to get into mischief. No breach of discipline has ever occurred, with the exception of one student from a foreign country, who seemingly could not rise to American ideals. Instructors have the power to discharge delinquents from camp, just as on a regular engineering corps, and to cancel credit for the session. The case above cited was so slight, however, that no drastic action was needed.

None of our summer sessions have ever been looked upon as "snap" courses, and the students who were due have earnestly tried to get work in lieu thereof. Recalling how our earlier students seemed to value summer practice when it was not required for graduation, it is somewhat amusing to reflect on how they hunted for positions on engineering work as soon as it was known that the latter could be substituted for attendance at camp.

An increasing number, on the average, have thus profitably occupied their summer vacations, and the department thus far having been uniformly successful in getting work for the balance, it happens that for ten years past, every student in the department has been engaged in practical work before graduation.

It is no objection to the system that the experience thus obtained by a class as a whole will vary widely in amount and character. Indeed this is an advantage, for, in the work before the class in the lecture room, it arouses the members when points are brought forward from their collective experience. Instructors like to draw upon student experience, and students are encouraged to present their observations to the class, and frequently do so at length. They are also able to hold interesting sessions at the meetings of their civil engineers' club.

An interesting result of the plan of allowing substitution of outside work, and one not anticipated at the outset, is that an

increasing number remain out of school on engineering work for a year or more during their course in college. This situation is shown at present in the two upper classes. Thirty-five per cent. of the present seniors (class of 1913), and 45 per cent. of the juniors have remained out of school on such work for a solid year or more.

From reading as many of the foregoing descriptions of the camps of each year as may interest the inquirer, he will see that the practical summer sessions have in no wise furnished identical experience to each camper. Nor has this been the aim of the department in accepting such work. The aim has been rather to accept a real task, the accomplishing of which will forcibly illustrate to the student, the use of the instruments and methods of his calling. If it were not for the variety of work given each student on the campus, we would hesitate to accept practical tasks varying so widely in character.

We explain clearly to the students at the outset of each camp the nature of the task we have set ourselves to do with their assistance, the methods proposed for use, and the results hoped for. We invite their suggestions and questions at all times during the progress of the work, and explain the hazard run (it is always more or less of a hazard when using the immature students who have been unable to obtain positions) in binding ourselves to accomplish a given thing in a given time. Thus far they have not failed to rise to the situation and do their best at each session.

Little if anything is lost to the student by serving in fewer positions in practical camps, than he is scheduled for in the practice surveying camps. Something must be sacrificed and if variety is emphasized thoroughness suffers. A green hand in each position disorganizes the party, and gives no member of it an adequate idea of procedure or speed in problems of length. Frequent rotation will do for short exercises like those on the campus.

Then again in practical camps each fellow may get a reasonable variety not inconsistent with proficiency, if he has his

share of that quality, so desirable in an engineer, aptitude at observing. For example, a wide awake rear chainman may learn much by observing how each member of the party does his work on a well organized and efficient corps. Especially will he do so if he himself has had lectures and exercise in the same position on the campus during the year preceding, as is the case with all our men.

The chief advantage of the practical camp system is the *esprit de corps* encouraged in the men, not only in camp but throughout the college year. It is intangible but none the less valuable. When the student sees instructors attempting real problems and relying on each fellow to do his share, it encourages a spirit difficult to get in imaginary or practice problems. Instructors act not only as party chiefs, but in any capacity that will help the work along, and when they do this it is a rather hopeless student who will not get busy.

When the student sees his instructors accepting a task for summer camp that seems at the time difficult to accomplish with the men and means at hand, it opens his eyes in a most forceful way to some of the qualifications asked of him after graduating. Confidence of the student in himself is encouraged when instructors place more confidence in him than does the public. For example, the State Board of Public Works hesitated to give us the task of surveying Buckeye Lake, for these surveys were needed to stand the test of courts, and two previous surveys by private individuals had been unsatisfactory. The students, working under *experienced* instructors of course, were able to accomplish the task so well, that two years later the Board gave us a similar task at Loramie with twice the compensation.

Summary and Conclusions.

Summarizing conditions as they are with us, we may list them as follows:

1. Our freshmen nearly all come directly from the high school, and at least after the first year in college, need a maturer view of their schooling than they have previously taken.

2. Nearly all of them are of very modest means, and many have to help pay their way through college.

3. Far the greater part of them feel that they can not spend more than four years within college halls. This is suggested by the ratio of alumni to ex-students, using the latter name for one who has attended college more than one year. The figures up to date are as follows: 320 graduates to 487 ex-students.

4. Requiring five years in college for a professional or semi-professional degree would seriously reduce the ratio preceding, and perhaps reduce total attendance.

5. Entrance requirements are as stated at the outset of this paper, and it does not seem feasible to get much more maturity in our students by raising those requirements at present.

6. Our large college grounds, 450 acres in one piece, makes possible a schedule of field problems concurrent with theory, that is not practicable at every school.

7. Proximity of state, county, and municipal activities affords opportunity to make the department and its students directly useful to the public. In this way students with instructors have at various times been of service to the State by serving the following bureaus:—Adjutant General's Department, Board of Agriculture, Highway Department, Board of Public Works, Public Utilities Commission, and Trustees of the University. They have also been of service to the national government and to various counties and municipalities.

8. Demands of the practicing profession in this region for help from our students has steadily increased. This has operated to partly cut down attendance in the last two or three years.

9. The climate of this region is not so favorable during summer for doing class work along with field work, as may be the case in Maine or California, for example.

10. Our department classes are not large, and the work is so divided that all the head professors become well acquainted

with all our students before they finish the third or junior year, without going to summer camp with them.

There are tangible benefits resulting from substituting engineering employment for attendance at camp, some of which appeal strongly to the average college student.

1. He gets three months of experience during the summer in place of one, and although he does not get the variety, he gets a more thorough drill.

2. He gets pay for his work which makes it seem real to him, and helps him financially through college.

3. It heightens his sense of responsibility. This is usually needed at least by the younger students.

4. It extends his acquaintance in the practicing profession, a material help to him after he graduates.

5. They are of service to practicing engineers by supplying help when help is really needed.

6. It saves expense to the university.

However, for the chief benefits of the system of administering Summer Surveying Courses, as developed in the pages preceding, we will have to revert to the intangible acquirements that were listed at the beginning of this paper. If example may be as potent a teacher as precept, then we have used past practical summer sessions, to teach by example, as nearly as we can, what we try to teach by precept within college halls.

The civil engineer's chief laboratory is the wide world outside college, and if each immature student before receiving his diploma can be given a short course in that laboratory, whether it be under college instructors or other employers, it points him more directly than any other single course in the curriculum to many of the qualities which his whole college course aims to develop.

The educational value of work, even routine work, is often lost sight of; and if it has educational value, as undoubtedly it has, why postpone or neglect it altogether until our young men have taken their diplomas. The first duty of the graduate is to be useful in the world rather than brilliant; cleverness will flow from him naturally if he has it.

It is not primarily the education of the brilliant student that this Society is organized to promote. He will take care of himself, as is evidenced by the eminent civil engineers who never attended any modern college of engineering. It is that much discussed elusive "average college student," as he comes from the high school to us instructors in engineering.

It is his interest that has to be aroused. If you get him interested you have gone far to solve the problem. It is something of a task to do this in the class room, it is easier if you supplement recitations and lectures by field exercises on the campus, it is easier still if you take him to practice camp, and it is easiest of all if you put him on actual work, whether with instructors or with other engineers. The effect of this latter is certainly beneficial in teaching technology in the class room.

The practical camp system is doubtless not applicable at all other schools; but we much prefer it to the practice camp system, and hope to continue its use. Should our students in sufficient numbers fail to get work, and should we fail to be able to use practical camps in the future, we will fall back upon practice camp sessions, for the latter have advantages that are not inherent with such work as may be given on the campus.

DISCUSSION.

Dean P. F. Walker: May I ask two or three questions? First, am I correct in understanding that at The Ohio State University a fee is required from each student for instruction in the summer school of the University?

President Magruder: You are.

Dean Walker: Is it the practice at The Ohio State University and other universities to charge the summer-school fee where students in the electrical and mechanical engineering are required to do shop-work in the summer?

President Magruder: At The Ohio State University, yes; but you must remember that our tuition fee is smaller than in most institutions. That makes a difference.

Dean Walker: Do I understand that the fee for such stu-

dents is less than is usually charged the regular summer-school student?

President Magruder: Each of our summer-term students pays a six-dollar fee.

Dean Walker: So your engineering students pay the same fee as do the other students of the University.

President Magruder: Yes. All students are treated alike as to fees. In addition thereto, they pay for the materials they use in shopwork and in chemistry.

Our students have gone as far west as the Yellowstone Park, and were there for six weeks. The students paid their own travelling expenses and the government furnished subsistence.

Professor F. W. Sperr: Do these parties receive compensation for the work they do?

President Magruder: Sometimes. They are never promised pay. The table under "Practical Sessions" in the paper exhibits what has been done in the past. It depends upon the kind of contract the instructor in charge is able to make and the party's success in completing the work. The pay to the students has ranged from $1.75 to $2.75 per day.

Professor Sperr: Does the surveying party consist of the professor and his helpers standing in the relation of engineer and assistants?

President Magruder: Yes.

Professor Sperr: Who gets the compensation, the professor or the student?

Professor E. F. Coddington: The instructor gets his regular salary in the first place, and then what is made from the contract is divided among instructors and students, after the expenses have been paid.

President Magruder: To illustrate; there is a tremendous amount of surveying work being done in central and southwestern Ohio at the present time. Over a score of bridges went down in the recent flood and nearly a hundred lives were lost in our county alone. Hence the city of Columbus says to the instructor, "Will you take the job of surveying the Olentangy

River northward from its junction with the Scioto?" "Will you take the job of surveying the Scioto River from where it joins the Olentangy southward so many miles?" The city and the instructor agree on the price and the contract is signed. The report is called for by a certain date and the data must be in and correct.

Professor Chandler: How many instructors have you in the field with the surveying party?

President Magruder: That depends entirely upon the size of the party; from one to three, and sometimes more.

Professor Chandler: And how many students?

Professor Coddington: The smallest number for one corps would probably be six students. We might have two corps, twelve students, or possibly three, according to the number of those who had not found practicable employment. We make up the party accordingly from the material at hand.

Professor Sperr: I wish to call attention to one feature of this matter that bears somewhat on other topics that we have discussed, namely the relative advantages of the practical camp and the practice camp. We have a practice camp all the time, and live in it and expect to maintain it for many years to come. Now it seems to me that in the practical camp, it is difficult to adapt the work to meet exactly the educational needs of the students, the incessant and comprehensive drill in fundamental principles.

FOUR VERSUS FIVE OR MORE YEARS OF ENGINEERING EDUCATION.

BY G. F. SWAIN,

Professor of Civil Engineering, Harvard University.

I must confess that I am somewhat of a pessimist on the subject of modern education and its results. The longer I live the more I am convinced that an education in the university of hard knocks is the best kind of a training, and that the colleges and technical schools are under a great temptation, to which they generally yield, to relax the discipline without which a young man will not gain the habits necessary for success. There is a great tendency to teach facts rather than reasoning, and there is too great a tolerance of poor work.

In these respects, the engineering schools are far less open to criticism than the colleges, because they deal more with concrete things, and because the student learns *by doing*, to a greater extent than in the study of the so-called humanities, which are taught mainly by lectures. Moreover, in the study of engineering, the student is studying subjects in which the truth of his results and the accuracy of his reasoning are subject to test, which is not the case in many of the subjects making up the usual college course, except in natural science.

For these reasons, I believe that a four-year course is long enough for the large majority of engineering students. I have no question, however, of the truth of two other statements, namely:

1. The four-year course in engineering should not be a highly specialized course, but should touch mainly the fundamental principles. It should also broaden the student's point of view by giving him some knowledge of related sciences, of literature, history and economics, so that he may be informed

regarding the problems which confront him as a citizen and as a social being. He may thus be stimulated to continually broaden himself in these directions throughout his life, thereby adding to his power and influence as a man among men, and to his possibilities of enjoyment. Our four-year technical courses are too narrow and aim to carry men too far in special lines.

I have often stated and reiterated these beliefs and will not here develop them farther.

2. The exceptional man, that is to say, the man who can profit by collegiate study, should have the opportunity, and should be encouraged, to take a longer period than four years for his engineering education, not only in order to pursue his technical subjects to a higher point, but to broaden himself still farther in the humanities. Five- or six-year courses should, therefore, be provided *in a few schools but not in all;* but care should be taken that no one who is not qualified by temperament and preparation to fully profit by such longer courses should be encouraged or allowed to take them. During this course, the vacations should be devoted to practical work in the shop or the field.

FOUR VERSUS FIVE OR MORE YEARS OF COLLEGIATE EDUCATION.

BY ALEXANDER C. HUMPHREYS,

President, Stevens Institute of Technology.

Under the above title I have been asked to prepare a paper for this meeting. I shall confine myself to collegiate education in preparation for the profession of engineering.

Among educators there is a strong and growing opinion, I fear, in favor of extending the four-year course which, for some years, has been the standard in the United States. The lengthening of the course naturally is suggested as the remedy for the crowding of the curriculum which has as naturally resulted from the rapid advances in engineering science made in late years. This remedy is the one on the surface, but it by no means follows that it is the best remedy.

The differentiating of the engineering profession into so many specialties, which has been more and more in evidence in late years, has also been used as an argument in favor of the proposed change. This may be used quite as cogently as an argument against the proposition.

Here in the United States, while the more general proposition is to extend the undergraduate course to five years, there are not a few who favor extending it to six and even seven years. As the claims are presented for more advanced study in some branches, and for the inclusion in the curriculum of new subjects, it is to be expected that those in authority will take the path of least resistance, and so propose that the students shall submit to a further reduction of the portion of their lives remaining to be devoted to productive effort.

Particularly is this suggested remedy to be expected from the heads of the departments directly concerned.

The same tendency is to be seen in our every day life. As our needs, or our luxuries which we often mistake for needs, increase, the remedy at once suggested is the securing of an increase of income. In this case we might well consider two questions:

Will our lives be more complete if the new wants are satisfied? Cannot the income already in hand be spent to better advantage? May we not apply these tests to the question before us?

Will our students be more completely equipped for their life's work by giving them additional collegiate education? Not necessarily. Because there is a need, and a growing need in our profession for more instruction and training than can be covered in a four-year college course, it by no means follows that the colleges must charge themselves with the entire responsibility thus indicated. Have the colleges of engineering at any time in their history given their students a complete training for life's work and responsibility? The question needs only to be asked to be answered in the negative.

The college training in engineering is of great value to the one who takes advantage of his opportunities. The college affords the opportunity for acquiring a sound *fundamental* training within the shortest time and with the least expenditure of mental and physical energy. But this college training is not a necessity in the case of the men, perhaps exceptional, who have the brains, physical strength, and determination, to persist in the face of difficulties.

Let us not forget that in every walk of life there have been and are now to be found men in the front rank who never had any college training and some who had little school training. It is true these were or are extraordinary men and must not be taken as patterns in planning for those of average capacity. But at least we can learn from the careers of these men that education can be obtained outside of academic surroundings.

Then should not the man of good ability and character be able to study effectively by himself after four years in college, following the years spent in the primary, grammar and high schools? Certainly he should be, provided he has been taught how to study and reason rather than crammed with facts and information.

Is it not a fact that if he were to become a master in any branch of the engineering profession, the student, in the past, found it necessary to make himself proficient and efficient after he had graduated from college? If this was true in the past, are the present conditions so different that in the four years of undergraduate work the student cannot acquire a sufficient grasp on science and mathematics as will enable him to reach the highest attainable rank *for which his personality qualifies him?*

No doubt some of those who graduate after four years will not, and perhaps could not, build a sufficiently high and strong structure on their college foundation to enable them to reach the loftiest heights of professional eminence; but this proves nothing. This measure of success involves more than formal education; it involves the questions of natural ability and character. Furthermore, there is not room for all at the top.

Are not we of the engineering colleges too apt to be led astray by thinking that we must turn out a finished product? Is it not true that too many educators believe, or at least act as if they believe, that all education is to be secured only within the school, college and university? A great many believe, or act as if they believe, that all culture must be so secured.

When the question is put to us squarely, we must all admit that this is not true, even as to culture. Certainly then it cannot be true as to technical education. Let us be frank and go farther and acknowledge that there is much which the engineer needs, if he is to gain eminence in his profession, which cannot be acquired in college, though he were to remain there to the end of his days. The college may develop scientists

but it remains for the school of experience to complete the training of the engineer, as far as it can be completed.

This question of the extension of the undergraduate years of study cannot be intelligently considered until we give adequate credit to the opportunities afforded by the combination of practice and study in the school of experience. If we are persuaded that some time should be added to the undergraduate course, how much time shall we add? Will one more year meet the demand created by the advances made and being made in engineering science? If not, will two years, three years, four years, five years, enable us to give our students a complete knowledge of all that is comprised within the limits of any one major branch of the engineering profession? We have only to consider the limitations to the knowledge of those who have devoted a life time to study in one branch of science to force us to negative this question.

Is it not true that if a man spent a life time within the college walls, when he found himself dying of old age there would remain much for him to learn? As a general proposition, is it not also true that as his time as a college student was lengthened, he would become less and less capable of applying his knowledge of science and mathematics practically and commercially? And here let us not forget, if we exclude the military branch of our profession, he is not an engineer who is incapable of meeting the conditions of fair commercial competition. I am prepared to go much farther and say that as there are two sides to every question, there are two sides to the question of college training even when limited to the four years. While unquestionably, in the case of those naturally qualified for advanced study, the balance is in favor of the college training, there is a minor disadvantage to be reckoned with, and this increases with the years spent in college. This disadvantage is the too great reliance which the *student* places on his college training and his failure to recognize and keep constantly in mind that his college work is only preparatory at the best. Furthermore, with weaker natures, the longer a man remains a student, only the less is he qualified to battle with, and the more he shrinks from, the stern realities of life.

Now let us briefly consider the second test question. Can the time now spent in school and college up to graduation from the four years college course be spent therein more economically and efficiently? In considering this question we include the preparatory work in the graded schools.

The first thought that here comes to my mind is that the men who graduate from the Stevens Institute of Technology, average in age about 22½ years. It would seem as if a man should be a producer as well as a student at that age—a student he must remain in any case.

If we are to criticize the work of the schools in preparing our material for us, we must be sure that we are using our four years to the best advantage. Are we doing so? I believe that in some of our engineering schools we cannot do much more than we are doing. Certainly we cannot do better by crowding more into the curriculum. In some cases better work can be done by attempting less; by giving the students greater opportunity for assimilating that which is offered.

Perhaps the best opportunity for a more effective use of our four years is in the coördination of the several branches of study. Those in authority must be alive constantly to the necessity of watching for and providing against the over development of any one subject and the unnecessary overlapping of two or more subjects. A course in engineering, or any professional course, can be kept in balance only by constant effort on the part of those in authority, and the loyal coöperation of the whole teaching staff. The conscientious, ambitious professor especially is inclined to increase his demands on the students and so rob the other professors of their share of the time and energy of the students. This is particularly so with a professor of engineering who is fully alive to the progress being made in his specialty. Here it is to be remembered that, with a class already working to a reasonable upper limit, if some new illustration of principle is to be introduced, it must replace some other illustration to be abandoned. Frequently this can be done without any loss educationally.

One thing is certain—just so soon as we give our students more to do than they can do thoroughly and with some degree of comfort and satisfaction to themselves for work well performed, we are not working them efficiently.

The question will here be raised—What grade of capacity and ability shall we take as a standard? Shall we adapt our requirements to the brilliant student, the student of good average capacity, or the student who learns slowly?

We can at once eliminate those who are lazy, indifferent, or who pay *too much* attention to athletics or other student activities or any other interests than those connected directly with the course of study. I say too much attention to these other matters because I believe the students should be encouraged to give some of their time, thought, and energy to student activities. We can sympathize with the earnest student who learns slowly, but it is not fair to hold back the majority for his benefit. He must take an extra year if necessary to complete the work of the four years. Of those who are naturally qualified for the engineering profession and are really in earnest and ready to devote themselves conscientiously to their studies, there should be comparatively few to take this extra year. If there are, it is a warning that the work of the several departments should be investigated. Certainly we cannot fairly adjust our courses to the exceptionally brilliant men. Nor need these men feel that they are losing time by having to mark time to enable the average men to keep in line. There is plenty for the brilliant men to learn and do if they have spare time and are willing to employ it sanely. On the average, I think those who come midway between the extremes named must furnish us with our gauge. And it is not unlikely that a large percentage of the really successful engineers will come from this section. They often make up in common sense what, by comparison, they lack in so-called scholarship.

While I do not look for any great improvement in the case of some of our colleges through a more efficient employment of our four years, I do believe that some educators who are warm advocates of extending the four-year course would do well to

examine themselves and their teaching carefully and frankly to determine if they are doing their best for their students in the time allotted; and especially *if they are loyally coöperating with their associates* in *securing* and *maintaining* the highest attainable coördination of the course as a whole. I am inclined to believe that a completely competent investigation of our colleges along these lines might be highly instructive and point the way to increased efficiency.

Now let us for a moment turn to the question of the quality of preparation as furnished by the graded schools. Is there one among us who believes that it is what it should be, or even what it might well be if we would throw away our prejudices, stop boasting, and really coöperate to improve conditions? At least let us not attempt to avoid responsibility by sticking our heads in the sand.

The first step should be to eliminate politics. A hard step to take in a country such as ours. If we cannot eliminate this dangerous influence, let us be frank and brave enough to acknowledge its presence wherever and whenever found.

The greatest fault, in my opinion, is that we hold the college out as the goal for all. We even deplore the fact that so few of those who enter the public schools, and especially the high schools, go on to the college. No doubt it is a cause for regret that certain ones do not go forward, but it is by no means a cause for regret in the case of the great majority. Many a good clerk has been spoiled by trying to make him into a teacher, lawyer, doctor, or minister. Many a good mechanic has been spoiled by trying to make him into an engineer. And I am speaking from experience outside the college as well as inside. Our object should be to educate the masses for self-support and so for self-respect. This would work no hardship to those going forward to the college; whereas the present system does work a hardship for the great majority.

Another fault is that we do not regard with sufficient respect the duties of the teachers in the primary grades. They should not be considered as teachers of lower rank. If they do their work efficiently, the problems to follow are greatly

simplified. It is natural that the teacher should try for the step which is regarded as promotion. It is unfortunate that so much of the poorer teaching material is saddled on the primary grades.

A decided advance towards the solution of the problem we are now considering would be made if there could be a material increase in the salaries of our public school teachers, especially in the primary grades. And then there should be a commensurate increase in the required qualifications, and particularly in the *ability to teach.* There are many teachers and professors who possess but little of this ability. They may know, but they cannot make others know. Many of these misfits are temperamentally disqualified from doing the work of the classroom.

First of all, then, the pupils of our schools should be thoroughly taught and drilled in the "three Rs" and other fundamental studies. And here I am not speaking of preparation for any particular line of study to follow, but for the future in any line of effort in study or for self-support. I am afraid that we of the engineering colleges allow ourselves to forget that the lack of complete *facility* in reading, writing, adding, subtracting, multiplying, and dividing, is a constant handicap to the student, pressed as he is for time. It is like giving a mechanic a poor set of tools and requiring him to perform his task accurately and *on time.* I am old-fashioned enough to believe that in our efforts to make the school studies less wearisome, we are weakening the students as to their powers of concentration and perseverance. This and the crowding of the curriculum have unquestionably led to superficiality.

There is also room for improvement in the matter of discipline. Our children should be taught to do right because it is right; failing to respond to this treatment, they should be taught that they must do as they are told to do. As far as possible they must be taught to govern themselves. Failing in this they must be governed. This would help in no small degree in better preparing for life's work, including collegiate study.

Here, as in every well-considered scheme, educational or otherwise, extremes are to be avoided and balance is to be sought constantly. Let the children from the first be taught to find pleasure in work well and thoroughly performed, not in work easily done. Time and energy might be saved by reducing the demands for memorizing facts. Let this line of instruction be kept to a minimum and the children early taught how to find their facts and reason correctly therefrom. I know it is argued by many experts that the memory must be cultivated. Again it is a question of balance. The brain can be so overtaxed as to be distinctly injured as a memorizing machine. Some are endowed with wonderful memories, and this is a most convenient tool for rapid and easy execution. But I have often found that unusual memorizing ability is not coupled with capacity for sound reasoning. Here and in other places I shall be misunderstood. I can only repeat, I am arguing against extremes, knowing positively that in too many cases extremes are in control.

After all, the proof of the pudding is in the eating. The average age of those entering Stevens is about 18½ years. Many high school graduates fail to pass the entrance examinations, and fail in the fundamentals. When we compare with the age at which the A.B. degree used to be taken, it is evident we have extended the years of preparation. Is the improvement in preparation commensurate with the years added? My answer is an emphatic "No."

Certainly, when we consider that we do not graduate our men until, on the average, they are over 22 years of age, we should very seriously consider every step of their educational progress, from the primary school forward, before we further reduce the working life of our young men. Especially should this point be conscientiously considered when we reflect that adding to the years in school and college *tends* in some directions to make the student less effective as a practitioner. Again a question of balance.

In conection with our investigations looking to greater economy in time, we may well keep our minds open on the

question of coöperative education as practiced for many years in the University of Glasgow and, as now well under way in a somewhat different form, in the University of Cincinnati. There are arguments for and against this scheme. The question is—which have the greater weight? Certainly the plan has the great advantage of combining practice with theory—the advantage which the graduate has, if he will avail himself of it, in studying while he practices. The results obtained by the Glasgow University speak well for their system.

The economic questions which are pressing for solution to-day and which threaten the peace and prosperity of the country, place a great responsibility upon the engineer, for he should be capable of giving material aid in the solution of these questions, so many of which have to do with the industries and public utilities. But we find the engineers of the country frequently wide apart on fundamental questions which are referred to them, and generally because these men have not been sufficiently trained on the investment feature of engineering. Engineering practice cannot be divorced safely from sound business practice. The weakness is evidenced in the attitude of bankers towards engineers' estimates on construction and earnings therefrom. While conditions have improved of late years, because the men who control the money are more careful in selecting their technical advisers, we still hear the criticism, "Is that an engineer's estimate? Then add at least 50 per cent."

This may be considered an argument for extending the course. But better less theory, as long as it is accurate as far as it goes, and greater capacity for commercially practical application. At least let our students be taught that before or after graduation they must learn what the capable clerk has been learning outside the college during the college four years; and especially that he must learn the *principles* of accountancy, including such matters as depreciation; analysis of records; specifications and contracts; elements of banking, and the like.

Apart from the demand for more time for the engineering

course, there is coming to be a demand for a longer undergraduate course so that more time may be given to the so-called cultural studies. Are not too many of the professional educators particularly inclined to act on the belief, even if they do not hold to the belief under cross-examination, that the cultural studies are to be distinguished by labels, and that this intangible something we call culture cannot be acquired outside of the college or university? I do not propose here to be misunderstood as I have been at times. I believe the engineer requires all the culture, breadth of judgment and sympathy with his fellows that he can acquire or cultivate. Certainly he needs these as much as the member of any other profession; but the culture may not always take the same form. I have met people who were cultured in the ordinary acceptance of the term, who were out of touch and out of sympathy with the world in which and by which they were living; who had a store of knowledge, but with little ability to use it for their own good or the good of others; and who were unable to form a sound judgment based upon the stuff stored in their brains.

The strictly engineering studies can be so presented and taught as to have a truly cultural value. Do not let us extend our courses only for increase in opportunity for culture, unless we are sure of our ground.

In estimating the educational equipment of our graduates, let us compare, not with what we think we know and can do after ten, twenty, or thirty years' experience since graduation, but with what we actually knew and could do on the day of graduation. Here is a mistake frequently made by the practicing engineer as well as by the educator.

It is quite in order that I should say a few words about post-graduate study. I have been misunderstood as condemning post-graduate study, and particularly at a dinner last winter given by the alumni of one of our colleges of engineering. For those temperamentally and otherwise qualified for the work, I believe thoroughly in college post-graduate work in engineering. Those men are the exception. Many who take up

this work would do better if they went out into the world to try to earn a living by putting into practice what they have learned in college. I am most firmly of the opinion that after four years in college the great majority of graduates would do better by securing their post-graduate training while practicing their profession. Even research work of the highest order is being done by men so engaged. The colleges are constantly profiting by the results thus obtained, carried back to the college for the benefit, not only of the undergraduates, but of the post-graduate students and even the professors.

But again there is the confusion of terms so common in the United States. What is post-graduate work *in engineering?* We hear that certain institutions are carrying on post-graduate work in engineering, when, upon investigation, we find the engineering studies are only those included in the regular four-year course. The post-graduate feature consists in the requirement that the students shall have first taken their A.B. or the equivalent. This is, in a sense, post-graduate study, but it is certainly not post-graduate study in engineering. The institutions which claim thus to do post-graduate work in engineering are, consciously or unconsciously, deceiving the public. All of our engineering colleges of first rank receive students who have taken their A.B., but I have never heard it claimed that these men are doing post-graduate work in engineering. One advantage these men have over those who are taking the so-called post-graduate studies first referred to is that instead of being in a class by themselves they have to keep pace with men who are required to work diligently if they are to graduate, and so they in turn are forced to apply themselves in a way which they probably had not been required to do in their previous college work. They have a better chance of acquiring habits of industry.

In conclusion, let me suggest, it is because so many college men allow themselves to be found advocating views, which at least appear to favor the claim that the college and university hold a monopoly of all educational forces and agencies, that the opportunity is furnished for the attacks on the

colleges and institutes of technology, such as those voiced by the late R. T. Crane, of Chicago. The extreme statements on the part of the college man bring out still more extreme statements on the part of the self-made man. Again it is a question of balance between two extremes. Let us think seriously of this before we decide to hold our students longer away from the educational advantages offered by the school of practice and experience.

THE FIVE-YEAR ENGINEERING COURSES AT THE UNIVERSITY OF MINNESOTA.

BY FRANK H. CONSTANT,

Professor of Structural Engineering, The University of Minnesota.

The length of an engineering course is not the sum of a series of accretions added on at the whim of the faculty so that, as President Humphreys says, if five years why not six, and so on, *ad infinitum*. If lengths of courses are determined in this way it is just as logical to ask, if four years why not three, and if three why not two, and finally, why send our boys to college at all. After all, except for custom, what is there sacred about four years. Education is like a living organism, growing and adapting itself to the changing conditions under which it lives. What was best for yesterday is not necessarily best for today. I have been asked to present the five-year viewpoint. I can only state what seems to be best under the conditions which confront us at the University of Minnesota. Some other length of course may be more suitable elsewhere as well as for some of our own students.

Comparison of 4-Year and 5-Year Courses.

The length of the course is determined by the needs of the curriculum, but it is subject always to a profound revision whenever it can be found to be detrimental to the student's best welfare. The discussion then hinges upon what is the proper curriculum and whether the student's interests are advanced by such a curriculum at the sacrifice of time involved. The accompanying charts give the outline of our five-year courses. They differ essentially from the old four-year courses in having two years of language, one year more

Post-Senior.

1st Semester.

C.E.

Structural Des.		5
Reinforced Concrete		3
Foundations		2
Electric Power		3
Thesis		3
Exper. Lab.	3	4 or 3
or		
Railway Eng.	3	
or		
Hydraulic Eng.	4	
		19

E.E.

Alternating Currents	2
Thermodynamics	3
Elect. Eng. Practice	2
Elect. Lab.	3
Elect. Des.	3
Exper. Lab.	2
Thesis	2
Elective	3
	20

M.E.

Thermodynamics		3
Exper. Lab.		3
Meas. of Power		2
Machine Des.	4	4
or		
Railway Des.	4	
Heating and Ventilation	3	3
or		
Railway Technology	2	
Mech. Eng. Elective	2	2
or		
Elect. Eng. Practice	2	
Elective		3
		20

2d Semester.

C.E.

Sanitary Eng.	2
Thesis	5
Electives	12 or 13
	20

Approved Electives:

Structural Des.	5
Swing Bridges	4
Reinforced Concrete	3
Railway Eng.	3
Railway Admin.	3
Municipal Eng.	5
Water Anal.	3
Bacteriology	5
Rivers, Harbors and Canals	2
Geodesy	3

E.E.

Alternating Currents		3
Elect. Eng. Practice		3
Elect. Lab.		3
Elect. Des.		3
Telephony	2	2
or		
Turbines	2	
Thesis		3
Elective		3
		20

M.E.

Turbines	4	
Specifications	1	
or		5
Ry. Administration	3	
Locomotive Con.	2	
Machine Des.	4	
or		4
Railway Des.	4	
Meas. of Power	2	2
Locomotive Testing	2	
Exper. Lab. Gas Engines		3
Thesis		3
Elective	2 or	3
		20

certain general principles and subjects. It is finally agreed, for instance, that a course should not be too technically narrow but should train broadly and humanly. In lengthening our course we did not increase, as President Humphreys suggests as the principal reason for such extension, the amount of technical work, the inclusion of more prescribed specialties (although there is room for many such as electives) and the more advanced study in such branches. On the contrary the amount of technical work was not materially increased but was generally moved along a year, so that what was formerly senior now became post-senior, what was junior now became senior, etc. The number of credit hours was reduced so that better and more intensive work could be done, and the remaining gap in the earlier years was filled with the broad general subjects which it was believed would make for better educated men and therefore better engineers.

Of course, in order not to congest the last two years too much a little of the engineering work had to reach farther back than formerly, such as surveying, railway field work, elements of electricity, etc., and our experience seems to indicate that this is wise, for it enlists the interest of the students and makes them feel at an earlier date that they are really in an engineering course and working to a professional end. By

placing the technical work near the end of the course there was room to spread out and strengthen the earlier preparatory work and to introduce the cultural subjects and electives mentioned above. You will notice that we require one year of English and two years of German or French. For electives some of the students elect logic, psychology, more English, history, etc. A good many, of course, simply elect more engineering work.

Details of the 5-Year Courses.

Discussing the curriculum more in detail I think most of the subjects are those deemed essential for engineering courses everywhere. Thus mathematics, English, drawing, physics, chemistry, shop, some of the general sciences, economics or political science, and the list of technical subjects, were in our old course and are generally found everywhere. We may split on the value of modern languages and very likely upon the length of time required for each subject, and here secondary preparation and local conditions play an important part. Four years of mathematics may seem a good deal but in Minnesota the students come rather poorly prepared in this subject and much of the freshman year has to be spent on algebra and trigonometry. The higher mathematical work is now better done and a course in dynamics has been introduced in the third year. This leaves more time for the important subjects of strength of materials and hydraulics in the fourth year. Some may think that more of the drawing should be given in the technical courses but when the drawing department is manned with technically trained instructors who understand the kind of training needful to the engineer, it is a great relief to the technical departments to have the students come to them with the ability to make real and presentable engineering drawings. Time is thus conserved which may better be spent upon engineering principles than upon the mechanical details of drawing-making. We have not thought that one and one half years of physics for the civil

engineers and two years for the electrical and mechanical engineers are too much for such a basic subject. We require a year of chemistry for entrance and give a year in qualitative analysis.

When I asked the post-seniors near the close of the year whether this was too much time consumed in the course one voice immediately cried out "not enough" to which there seemed to be no dissent. All will agree that engineers should have at least one year of economics or political science if they are to be more than narrow technicians. We believe that two years for these subjects covering elementary economics, transportation, American government, and engineering law are not too much. All will agree, too, that short courses in geology and astronomy are desirable for the civil engineers and that mechanism and kinematics, which they parallel in the other courses, are essential for the mechanical and electrical engineers. Educators will probably always differ as to the amount of time to be given to shop work, with a slowly growing tendency toward a reduction. We made no radical change here but slightly increased the amount for the civils in order to make the freshman year alike for all courses.

Modern Languages.

I hesitate to venture upon the discussion of modern languages in a prescribed engineering course knowing how strongly both educators and engineers are divided upon this matter. We tried to enforce an entrance requirement of two years of language, but in adapting our requirements to the uniform standard of the rest of the university the language now becomes a minor series which may or may not be offered. For some, then, the college language is all that they will get at any time. The strongest pedagogical argument against the language, aside from the cost in time, is the difficulty in enlisting the interest of students. When I put the case of languages to vote in the post-senior class I was rather surprised to find that more than half the class promptly voted

in favor of retention. In these days of world research in science and engineering, world trade and world travel, all will agree, I suppose, that a broad education should include some knowledge of one or more of the European languages, if for no other reason than to provide a foundation upon which to add later, should the necessity and opportunity arise. But no man, especially a busy engineer, will attempt to acquire even a reading knowledge of a language like German if he has had no previous instruction. Two years will seem inadequate to many. They should be more adequate than they are with better methods of instruction. When the college course follows two years of high-school work in the same language a good knowledge may be aquired, even with indifferent instruction. I invite further discussion of this important subject.

Technical Subjects.

However high-minded a faculty may appear in fixing upon the neutral and general subjects of the curriculum, as President Humphreys suggests, each technical instructor is inclined to view his own specialty with a certain bias or closeness of vision which throws his perspective askew. For this reason I might with better grace pass over the technical end of our curriculum merely inviting your candid criticism. But I may state again that these groups were not materially changed, only readjusted and rendered more elastic and elective, and the total amount of time was kept about the same as in the old four-year course. After all, the main business of an engineering college is to teach engineering and it is not necessary to be too apologetic for the technical courses. A fine balance must be struck whereby the interest of the students who enter with the single-minded purpose of becoming engineers will be enlisted fairly early in their course, and kept. There is no doubt that the engineering courses draw out this interest as no others do and, as President Humphreys has said, when they are properly taught, the strictly engineering subjects may have a direct cultural value. I do not think that our students spe-

cialize too much although they are given an opportunity to do so to a greater extent if they desire. In structural engineering, for instance, we find that three hours per week throughout the senior year is not too much for a thorough grounding in stresses as covered by such a book as Professor Marburg's, while one semester in design in the post-senior year, required of all civil engineers, covers just plain bridge design and a continuation of stresses in higher structures. One semester in reinforced concrete is also prescribed. But in the second semester of the fifth year, while our department offers several higher courses, everything is elective. This year all of the class continued the work in reinforced concrete design and about sixty per cent. that in structural design. The major interest of the rest of the class was along hydraulic or municipal lines. Thus the amount of required structural work has been cut down but the amount which may be elected by those especially interested has been increased, but at the expense of the other technical subjects. The same statement is true of all of the courses. The courses thus become elastic and after the general broad foundation has been laid in the several related technical subjects, by elective segregation of the most interested students really much higher work may be accomplished in the technical courses than formerly. I would go farther and say, that if the occasional man comes along so imbued with the investigative spirit of the graduate student and so deeply interested in some one branch of engineering that he wishes to pursue his work in it beyond the ordinary undergraduate bounds, he should be given the opportunity to do real graduate work and receive the master's degree. I believe this is sound engineering pedagogics. For if the engineer should possess any one ability it is to be able to take up a new and complex problem and think upon it logically and consecutively until he has found all that there is in it and its solution. President Humphreys says we may not in a life time acquire all knowledge. But the student may be taught the method of penetrating the engineering unknown and this training is as useful in one branch of engineering as another.

Subdivision of the Student's Time.

Even should all agree on the content of a curriculum we might still differ in the required length of time for each subject. Could each instructor develop his course intensively and with the sole aim of bringing out the highest student efficiency, and could all the courses be so coördinated that there would be no overlapping nor repetition and the student be carried steadily and progressively on his way, the length of time might be reduced. We all recognize that this is perfection in teaching and the hardest thing to accomplish practically. With insufficient help for the correction of student exercises, which should flood a department office if the student is being worked efficiently, and with many calls other than the class room upon the instructor's time, he is generally compelled to accept a slower pace than he desires. I believe it will be along the line of more intensive teaching, of teaching as a fine art, that we are to make future progress. Whether we could save a year at Minnesota is doubtful.

Sequence of Courses.

The relative position of the subjects in a course is important. In general I believe all will agree that those of the first three years are approximately correctly placed. The important question hinges upon the position of the technical subjects and the general electives in the last two years. Should the emphasis in the technical work be placed in the fourth year and the fifth be reserved for the general electives, economics, political science, thesis and the general clean-up of technical subjects? We felt that this arrangement would be fatal to the practical success of the five-year course. If the young men feel that they are getting the major part of the engineering work in four years, they will naturally follow the line of least resistance and drop out at the end of the senior year, as formerly. Most colleges have tried the experiment of an elective fifth year, and with poor success. We had an elective five-year course for years, but few men took it. To be successful,

the fifth year must offer something which the young men feel that they must have and for which they are willing to spend another year. They will not come back for logic, economics, thesis and perhaps a few advanced technical courses.

Conclusions as to the 5-Year Course.

Returning now to the proper length of an engineering course it is evident that, having agreed upon the content of a curriculum, the length of time needful for each subject, and the total number of credit hours per week, the length of the course is merely a matter of arithmetic. With us it adds up to five years. Others with a modified curriculum beginning with a more advanced preparatory training, may find four years sufficient. We found four years too crowded; we needed five, and we simply expanded into them. We have never considered six years, because the need for another year has not arisen, and may never do so.

Student Welfare.

The best arranged curriculum in the world would be a failure if it did not make for the student's best welfare. I heartily agree with President Humphreys that a boy may remain in school too long for his best good. But why draw the line at four years? We know that some men would be better off if they had never gone to college, and for some two, or three, or four years are all that really do them any good. The question is how to make a course elastic enough so that men may drop out gracefully and find their niches in life when their time has come. We still have a four-year doorway. It is not certain that we should not have some earlier ones. Of course what we are now discussing is the proper length of course for the average student. It is not the mental work of the added year that is criticized, for engineers are students for life, but it is the withholding of the young man from the world of action and the exercise of his will at a time when he is psychologically ripe for a different kind of develop-

ment. Whether $23\frac{1}{2}$, 24 or some other number of years of age is the maximum beyond which he is harmed by further school life, will depend upon the man and the conditions under which he has spent his early life. In Minnesota our men come largely from the farms and rural towns. They are accustomed from earliest childhood to work. A census of the present post-senior class revealed the fact that every member of the class had been a money earner during the summers throughout his course and most of them during the college year. The average summer earnings were about $200. Such men are in little danger of will-atrophy or getting a distorted view of life and their relation to it. On the contrary it is their power of reflection that is in most need of development when they enter college. Their mental growth does not stop with the fourth year. The rate at which the present class matured during the post-senior year impressed me as unusual. It may have been caused by the wakening up due to the enlistment of their interest in professional work. The fact remains that they were not injured by the additional year but undoubtedly enter the world of action with greater confidence in themselves and power to perform than they possessed a year ago. Not one regrets the additional year which he spent here although several were put to a severe financial strain in order to return. When the seniors went individually to the post-seniors for advice they were invariably met by the response that they (the post-seniors) were glad that they had come back. Of course whether our new men come from farms or not they should be encouraged to work during the summers, preferably at engineering jobs. I like the German restriction which requires students in most of the engineering courses to get twelve months of practical work in shops, laboratories or field before the degree will be granted. Shoulder-to-shoulder contact at an early age with the men who work, before the latter draw into their shell of reserve, is the vital thing. The student will learn three things; men, what it means to work for others instead of always being served, and possibly some practical details of engineering.

Holding the Students for the Fifth Year.

The most ideal course will fail if it cannot draw or keep the students. We were among the first to establish a real five-year schedule and it was the part of wisdom not to be too radical. We wanted some students to teach and so the four-year exit gate was left, with the B.S. degree. This is not, however, merely a bait thrown out at the end of an incomplete course. The engineer of the future must be a broad and cultured gentleman in President Humphrey's sense of the term, as well as a man of technical skill. Breadth and culture should be the sure foundation upon which technical skill is to rest. Of the two it is more important that the college should supply the foundation, because practical experience in engineering will gradually overcome technical deficiency, provided always that the general cultural and preparatory subjects are so selected as to have an engineering trend and supply real needs in the engineer's training. Such subjects perform the double duty of helping to make broad and educated men and at the same time to advance them in the direction of engineering and make it easier for them to take up the purely technical side of their profession if by any chance they are unable to complete the full five-year course. Reasoning along this line we believe no injury is done to the poor and worthy man who may be compelled to leave at the end of the fourth year, for this training should make him a better engineer than the old, more narrowly technical, four-year course. At the same time the four-year gateway affords an excellent opportunity for the unambitious or weak man to drop out of college gracefully.

The most important crisis in the five-year course arises when the seniors, having received their B.S. degree, are weighing the practical value, to them, of the fifth year. The simple solution from the college point of view is to bring pressure to bear by abolishing the fourth year degree. Experience has now shown that we would not lose our freshmen. I believe, however, that the spirit of competition that now

exists is a wholesome thing for both student and faculty. The student will not return unless he is convinced that it is worth while. The college is thus put to the test and instructors are stimulated to make their work so valuable that not only will the immediate senior be tempted back but likewise some who have dropped out for a year or two of practical experience. An ideal condition would be that in which a constant stream of such alumni would drop back after a year or two of practical experience, for a final year of theoretical training. The fifth year, therefore, is something more than the fourth year shoved along. While nominally the subjects are much the same they can be treated in a more advanced way. The men are older, their fundamental training is better, they can be treated as somewhat more than seniors although they have not the full status of graduates. The courses can be developed from a more professional point of view. They should be made attractive, yet only incidentally informational, and should reach the heart of the subject both in theory and practical detail. They should be sound and thorough, appealing to both present student and past alumnus as necessary to an engineer's theoretical training, and worth the extra year in college. This may be a difficult standard for the college to reach but the latter is undoubtedly under a constant surveillance and there is an annual judgment day. The question whether the individual student will be injured or benefited ceases to be an academic one and each student answers it for himself, and in the last analysis perhaps he is the most competent one to do so. I believe, however, it is the prerogative, as well as the duty, of the faculty who believe in the value of the fifth year, to present their case strongly, attractively, and always fairly to the outgoing seniors, knowing well that the latter will seek other evidence from post-seniors and graduates alike before committing themselves. The faculty thus become the advocates of the fifth year, not the inexorable judges sending all alike up for another year.

Results Achieved.

I have already stated how the fifth year may become a real post-graduate year for the occasional specialist or investigator. As President Humphreys says, the proof of the pudding is in the eating. The class of 1913 is the first to finish the course. We awaited their decision a year ago with some anxiety and were more than gratified to have forty-six out of fifty-three, or 86 per cent., return for the last year. A rough census of the present senior class indicates that about 75 per cent., and probably more, will return next year. We grant the degree of engineer at the end of the fifth year. Possibly this was done as an additional incentive to the student to complete the course, but I do not think the fate of the fifth year at all depends upon the degree,—that is, I do not think the student would be greatly influenced by the particular name of the degree he will receive. Students who do not quite qualify for the B.S. degree at the end of the fourth year may, by finishing the entire course, receive the engineer's degree without the first one, or they may, by finishing up the four years' work before Christmas, get the B.S. degree then and the engineering degree the following June. In no event may they receive both degrees in the same year.

Engineering, as a profession, needs men of the highest type and most thorough educational as well as practical training. At the same time, unlike most of the other professions, it contains a multitude of gradually graded subordinate positions. The five-year course aims to educate a small group of selected men for the former and at the same time to furnish that intermediate training to those who drop out along the way to enable them to fill the lower positions. Ultimately every man will find the highest niche in which, by his training and his ability, he belongs.

Discussion.

Professor F. P. Spalding: Professor Constant has brought out very clearly the purpose of those who have adopted the

five-year curricula, namely, that it is not primarily to increase the amount of technical work that can be done, but to give the students a broader training. A criticism which has been persistently leveled at the engineering schools in the past few years is that the training of the men is narrow; that they become so extremely technical as to be unable to meet the requirements of the social environment in which they may later be placed. It is required of us, if we are to meet the needs of the students, that we, in some way, broaden their training. The demand is for men of better culture, which, in this connection, seems to mean versatility and breadth of view. When we speak of a cultural subject, I think that we ordinarily mean a subject essentially different from those which are necessary to the main purpose of the student.

At the University of Missouri we have adopted a five-year curriculum somewhat different from that at Minnesota. Our method is to put into the entrance requirements of the school of engineering two years work in the college of arts and science, requiring the student to present, as a part of the two years preparation, the mathematics, general physics and general chemistry ordinarily given in the engineering curricula. Adopting this basis of entrance we are in position to complete, in three years of work in the school of engineering, all of the technical work formerly given, and leave a small margin for elective work or increased requirements. We do not have the fourth-year degree that Professor Constant has mentioned. Our men receive no degree until they have completed three years of engineering work, so that we are working strictly on the basis of the five-year curriculum.

This scheme has not been in operation long enough to fully determine its effect upon the number or character of the students in the school of engineering. I gather from some of the remarks made here that the effect upon the attendance of students is considered so important as to be largely determinative of action in many schools. This requirement will necessarily produce some loss in the numbers of students in engineering, at least for the present. Indications are however that

this loss will soon be regained. There is, of course, a large apparent loss of students in the school of engineering due to the enrollment of the lower classes for two years in the college.

The Minnesota curricula as outlined by Professor Constant are, I think, open to criticism in that they require too many exercises per week of the students. Professor Constant's schedules call for a recitation, a lecture or a laboratory period each week for each hour of credit, and twenty such periods are usually required. The work done by the student in preparation is of more importance relatively than the exercise itself, and better results will be obtained by meeting the class less often and letting the student do more of the work. Our work at Missouri has been materially improved by reducing our requirement to fifteen hours per week. The result is to increase, rather than diminish, the total amount of work required.

Professor G. R. Chatburn: Professor Spalding has mentioned an important point with regard to the number of exercises per week. In Professor Constant's schedules there are some men who have as high as twenty-two credit points per week. If the student is supposed to give for each credit point three hours of his time, that would require sixty-six hours per week. Getting to and from the University may require six hours per week and meals nine hours, making a total of eighty-one hours in the six days, thirteen and a half hours per day. On the basis of a five-day week, sixteen hours per day are required. The student should have, in addition to this, some time for recreation, and for participation in student activities and, perhaps, a little time for sleep. I am not sure that he can get all of these things into a week. I agree with Professor Spalding that that number ought to be cut down. I would like to see in every college catalog, with the statement of every course of study, the number of hours estimated to be required for a lecture, a recitation, or a laboratory exercise. For each three hours of time required the student should have one credit point.

Professor E. F. Coddington: Professor Chatburn has touched on some very important facts. At The Ohio State University we

have investigated the number of hours required by the average student to do the work required of him and in my opinion it is entirely too large. It is not conducive to efficient work. I have had some experience in the past year which bears out my conclusion. Several years ago I taught mathematics to freshmen and sophomores. I was then transferred to the department of mechanics. After a year or so had elapsed I exchanged with one of the instructors in the department of mathematics and taught a class of first-year men again. I was surprised to find that the first-year men studied with much more efficiency than did the third-year students. After that year's experience, several years elapsed before I again taught a class of freshmen. I have just had this experience last year. I was again surprised at the refreshing interest of these men. They are enthusiastic, they work, they grow. On the other hand, the third-year men seem to have become "stale." They are willing to learn the things that they think will be of practical use to them. They have taken up more or less technical work, but they are not inclined to seriously think about it. They have quit thinking any more than is absolutely necessary. I am of the opinion that the crowding of the work is one cause of this lack of interest in the upper classmen.

This has an important bearing upon the consideration of the five-year course. We have just heard that in the fifth year the men seem to have acquired renewed energy. I should be pleased to see a curve showing where the minimum of energy and interest is located. Perhaps this occurs in the fifth year, but after comparing the course of study described by Professor Constant with what we give our men, I should not expect to find it there.

In the process of education there are two things to be acquired, one is growth and mental discipline and the other is the learning of facts. As I have observed it, the rate of this mental growth is highest at the beginning of a student's college career and it follows a downward curve until he graduates. As soon as he begins to accumulate facts, the rate of his mental growth seems to diminish. The result of this is that

when the average student finishes his college course he has a lot of facts that he cannot use. It is, therefore, questionable if it is desirable to extend our course for the average man to five years.

Dean C. M. Woodward: I have something to say in regard to the conclusions drawn by Professor Constant as to the conduct and vote of the students. It is a little dangerous, I think, to apply generally the conclusion drawn under the circumstances existing here in Minnesota. Professor Constant said in the very beginning that if the ordinary engineering subjects had been put into four years, and the cultural, broad and social subjects into a fifth year, the course would have been a failure. He did not object to it on the ground that it could not be done; that the four years could not cover the technical subjects, and the fifth year the other subjects. He objected on the ground that the students would not stay in the course. That is, the students would not remain to take the fifth year if it were wholly devoted to the additional subjects which had been put into his curriculum. So the students are obliged to stay here five years to get an engineering course. Therefore their decision to stay was hardly one that could be counted upon generally because it was a matter of taking the course or going without it.

We tried the five-year course at Washington University for a while, putting some of the advanced work into the fifth year. Some students took the course, but there was a great falling off of good men. They couldn't afford it. They had not reached the limit of their mental ability to get a formal education, but they were obliged to withdraw, and they did so. Everybody admits the value of more training, and we need not discuss that. It is a splendid thing for a man to know not only all the technical subjects but other subjects also. Let him get all the degrees he can. If he is the right kind of a man, he is a bigger man with them. But we are training the youth of the community and we ought to make it possible for them to come and get what they want in a reasonable time. Is it altogether satisfactory if only seventy or eighty per cent.

of the students who want the training can get it? Ought we not to legislate as it were, for the whole of the American youth who want these technical subjects, and let them get as much more as they can? Professor Constant said that the "unambitious" and the "weak" go out at the end of the four years. This is very objectionable; a boy doesn't like to realize, when he knows that he can go to school but four years, that he must be labelled "unambitious" or "weak." I don't think you should put the students from Minnesota or Missouri or any other state in that situation.

Professor Constant: It is not true that the men going out at the end of the fourth year are labelled unambitious or weak. As a matter of fact some of our best men do so and we know that they are good men. There are several good reasons why men may not come back. They may not have the funds; they may wish to go to other colleges or into practical work. One of our best seniors has just accepted a position with the American Bridge Company for a year, and I advised him to go. I urged him to come back also. It is not true then that the men who graduate at the end of the fourth year are simply the weak and unambitious. But it is true that there are weak and unambitious men who, perhaps, struggle along for four years, and who have not the qualities to make the highest type of engineers. We feel that such men are better off outside of the college, and the course gives them an opportunity to drop out.

With regard to the cultural work, I think we all agree that a certain amount of the right sort is essential for the highest type of engineer. Yet the student, with his more restricted perspective, in his eagerness to get started in his vocation, would not return, in general, for a fifth year composed wholly of such subjects. But they can be introduced during the course and it does not seem an unfair coercion to require him to take them in that way even though, by so doing, the course is lengthened. At the last analysis a faculty must assume the responsibility of making the curriculum.

SUMMER WORK IN INDUSTRIAL PURSUITS FOR STUDENTS OF ENGINEERING.

BY F. P. McKIBBEN,

Professor of Civil Engineering, Lehigh University.

Should engineering students of technical schools and colleges continue to have summer vacations of from three to four months? If so, how should these vacations be utilized; in work or in play? To the first question most colleges would apparently answer in the affirmative, for practically all schools in the United States give vacations during the summer months. It is probably also the concensus of opinion that these vacations should be utilized by the students towards some profitable end, and should not be wasted, but there are apparently few schools that make systematic effort to find employment for anything like all of their students during the summer recesses. The University of Cincinnati has adopted the coöperative system by which students in civil, chemical, electrical, mechanical, and metallurgical engineering spend alternate weeks in college and in neighboring industrial establishments during eleven months of the year, leaving one month for recreation. While these students are employed in the manufacturing plants they are under the instruction of university teachers and the system is therefore essentially one of instruction for eleven months out of the twelve. Their students in civil engineering spend eight months of each year under this alternate week scheme and also are employed three months on a prominent western railroad where they receive instruction from railroad authorities.

The University of Pittsburgh has adopted a modified arrangement of the Cincinnati plan in that its students are required to spend three months out of every twelve in some

industrial establishment. Both of these schemes are really extensions of the laboratory method of instruction, the laboratory in these cases being a commercial plant in which the student sees operations carried on in a large way. The Worcester Polytechnic Institute has for years done something of a similar nature for some of its engineering students who are given instruction in the university shop, wherein capable machinists, foundrymen and other workmen are engaged in manufacturing certain metal products which are afterward sold by the Institute. The students thus see manufacturing work carried on, but of course not under real commercial conditions. Here is another attempt to give the student some actual contact with the commercial world, but as this is given during the college year along with the academic work it is only a modified form of the usual method of teaching shop work in college shops.

Some schools utilize a portion of each summer for surveying or work of a similar nature which can best be done in a concentrated form, but in such cases only a portion of the summer is thus taken up. For example, civil engineering students at Lehigh University spend one month in surveying at the close of the junior year and students in some other departments of the university spend some time in the shops of the Bethlehem Steel Company under the guidance of university instructors. It is seen, therefore, that in most institutions the students are given vacations ranging from two to four months. It would be interesting to know how extensively summer work is engaged in by the students of technical schools and colleges. Now and then isolated attempts are made to get at the facts but no concerted action of any consequence has ever taken place. The civil engineering department of Lehigh University in October, 1912, collected data from the sophomore, junior, and senior classes as to the kind of work which the members of these classes did during the preceding summer and as to their earnings for such services. The accompanying table shows the summary. It indicates that out of a total of 98 men in the sophomore, junior, and senior classes, 76 worked to a greater

EARNINGS OF CIVIL ENGINEERING STUDENTS OF LEHIGH UNIVERSITY DURING SUMMER OF 1912.

		Seniors Months.	Juniors Months.	Sophomores Months.	Totals Months.
Kinds of work	Municipal engineering	3	2½	9½	14¾
	Machine shop	2¾	—	5½	8¼
	Engineering office work	13½	6¼	4½	23 1/12
	Non-engineering office work	3	5	13½	21½
	Construction	5½	8¾	6½	20¾
	Railroad engineering	8½	15 7/12	6	30 1/12
	Surveying	11¾	3½	1½	16 11/12
	Highway engineering	6	2	6½	14½
	Hydraulic engineering	2¼	—	—	2¼
	Farming	2	—	5½	7½
	Barbering	2	—	—	2
	Canvassing	—	—	1	1
	Total number of months employed	60¼	43 7/12	59¼	163¼
	Number of men reporting	41	27	30	98
	Number of men reporting having worked	30	20	26	76
	Average number of months employed for all men reporting	1.5	1.6	1.9	1.6
For students who worked	Average number of months employed	2.0	2.2	2.3	2.1
	Total earnings for summer, not including traveling or other similar expenses	$3,524.03	$2,282.25	$2,566.80	$8,373.08
	Average earnings per summer per man, not including traveling or other similar expenses	$ 117.46	$ 114.11	$ 98.72	$ 110.17
	Total earnings for summer, including traveling and other similar expenses	$3,904.13	$2,412.40	$2,843.20	$9,159.73
	Average earnings for summer per man, including traveling and other similar expenses	$ 130.14	$ 120.62	$ 109.35	$ 120.52
	Average earnings per month per man, not including traveling and other similar expenses	$ 58.49	$ 53.07	$ 43.13	$ 51.36
	Average earnings per month per man, including traveling and other similar expenses	$ 64.80	$ 56.11	$ 47.78	$ 56.20

Note.—This table does not include the graduating class of 1912.

or less extent during the summer of 1912. The average number of months employed by the men who worked was 2.1, while the average earnings for the summer per man, counting only those who worked, was $120.52. The average earnings per month per man for those who were engaged were $56.20. Of interest are the last figures in the table giving monthly earnings for the sophomore, junior, and senior classes, respectively, showing that while the average earnings of the sophomores were $47.78 as compared with $56.11 for the juniors, the seniors in turn exceeded the other two classes with an average of $64.80 per month. Whether the increased earning power of the senior is due to his college training, to his increase in age with its natural consequent increase in ability, or whether it is due to the experience gained in the preceding summer vacations is impossible to state. No doubt all of these things have some influence on the increased earning power.

A total of $9,159.73 earned by 76 students working 163⅓ months is very satisfactory and speaks well for the earnestness and ability of the young men whose efforts have been so productive. Of the 163⅓ months employed, only 31¾ months can be classed as of a non-engineering nature, leaving 131$\frac{7}{12}$ months of engineering work. This shows that 81 per cent. of the total time employed was spent in work of an engineering nature. In studying the accompanying table it should be borne in mind that the graduating class of June, 1912, is not included therein. It also should be remembered that the seniors would probably have worked a greater number of months had they not been required to spend four weeks of their vacation in the summer school of surveying.

These earnings are of interest not only in themselves, as showing what the students are capable of doing, but they have an important bearing as indicating the character of the instruction which the students are getting during their summer vacations while employed in various industrial organizations. To a young man who spends nine months of each year in study in college, three months contact with an active, efficient business organization is of utmost value not only from an instructional

standpoint but from the disciplinary as well. Where such a large per cent. of the student body has had this active touch with engineering forces, the esprit de corps can be only of the best. And it is a very fair question to ask whether a system in which the great majority of students are actively employed in useful pursuits under competent engineers and business men during one sixth of each year is not equally as good as, if not better, than a system in which the student is for the greater part of the year under his university instructors. Not that the latter may not be as good as the former, but that the instructor and practitioner working together would seem to be better than either one alone can possibly be.

An improvement is possible in the utilization of the students' summer vacations in that a more effective and more systematic method should be used by the universities to secure the right kind of employment for all of its students who are physically capable of doing summer work.

Discussion.

Prof. A. J. Wood (by letter): Under the head of Summer Practice Work, the catalogue of The Pennsylvania State College states:

> The students of the three lower classes who take courses in agriculture, engineering, industrial chemistry, or mines and metallurgy, are required to spend a specific amount of time in exclusively practical work. The object of this arrangement is to allow a period of uninterrupted practice in the machine shops, laboratories, fields, and mines; in making all necessary computations; and in other lines of practical and experimental work, which cannot be secured in the ordinary course of daily employment during term time.

Adhering to the purpose of this broad yet definite policy, students in the school of engineering have been required for the past three years to spend a total of eighteen weeks of approved summer work in the industries. The work thus done is entirely independent of college regulations, nor do the de-

partments make any special effort to arrange for summer practice with outside interests.

Three weeks of work of this character are counted as one college credit, equivalent to one hour a week of recitation work for sixteen weeks. A student failing to submit the full summer credits must substitute college work to meet the deficiency. However, nearly all of the students find employment during the summer months, bringing letters from their employers at the opening of the first semester.

As a result of careful observation in the department of mechanical engineering, covering a period of three years, the writer would note the following:

First: On the whole, this training supplements the college work, giving a better perspective of the relation of theory to practice, and enables the student to receive more from his engineering studies, especially in his junior and senior years.

Second: It awakens new interest in engineering and fits a man the better to bridge the gap between the college and the industries.

Third: It enables the observing student to decide with more assurance the branch of engineering for which he is best fitted.

Fourth: It gives him confidence and self poise with little concern but that he can prove his worth when out of college.

Fifth: Many engineers have commended the plan and have coöperated in furthering the work. One large company this year has taken five junior railroad mechanical engineering students who will have the summer work credited to their special apprenticeship course if continued after graduation. Herein lies a suggestion of one method in which the industries (with special apprenticeship courses) and the colleges may coöperate to mutual advantage.

Sixth: The above considerations are favorable to required summer experience. On the other hand many a boy working eight or ten hours a day for three months has not the reserve mental power of one who has had sufficient rest, providing that

the latter has not gone to the other extreme and formed habits of indifference, carelessness or idleness.

At The Pennsylvania State College, the plan is working successfully, the principal advantage being in the discipline under which the student earns his wages at a period when the lesson counts for the most. This training, independent of college control and yet required by the college, is thought to be a step in the right direction.

HIGHWAY ENGINEERING, AN ESSENTIAL OF THE CIVIL ENGINEERING CURRICULUM.

BY ARTHUR H. BLANCHARD,

Professor of Highway Engineering, Columbia University.

The present status of highway engineering in civil engineering courses throughout the United States is comparable to the standing of the work of the highway engineer in the mind of the American lay public and to a greater or less extent in the opinion of the engineering profession. The non-recognition by legislators of the necessity of placing the control of the administration, construction and maintenance of highways in the hands of well-educated and efficiently-trained highway engineers is reflected by the expressed attitude of educators in the allotment of the small amount of time which is devoted to undergraduate work in highway engineering in our universities.

Need for Highway Engineering Training.

The waste of millions of dollars annually in the United States will continue until the profession of highway engineering is placed on the same basis as structural, hydraulic, sanitary and kindred branches of civil engineering. England, France and other European countries have seen the light. As a result efficient highway engineers are retained in office, organizations are perfected, methods of construction and maintenance suitable for local conditions are employed and as a consequence the public funds are wisely and economically expended. It appears to be the duty of educators to carefully consider the advisability of revising time allotments to engineering subjects with a view to giving more recognition to highway engineering.

The multiplicity of positions which should be filled by broadly educated civil engineers having a comprehensive knowledge of highway engineering will be covered in several papers prepared by experts for the Symposium on Highway Engineering Education. In this introductory paper it is advisable to merely call attention to the character of the positions which are being filled to-day by highway engineers. Such positions are found in state, county, municipal and town engineering departments, contractors' organizations and the engineering and research departments of companies manufacturing road machinery and materials used in highway engineering. Without doubt in the comparatively near future the national government will likewise call for many men especially trained in this branch of civil engineering.

Content of the Highway Engineering Curriculum.

In order that the civil engineer in embryo should enter on his life work at graduation with as general a knowledge of the field of highway engineering as of other branches of civil engineering, it is necessary that considerable attention should have been given by him to the following subjects: A study of the historical development of highways exemplifying the interrelationship between social progress and the improvement of public traveled ways; preliminary investigations, surveying and mapping, peculiar to highway engineering; the general design of highways, and a consideration of the methods of construction and maintenance of the many classes of roads and pavements which exist, which study would include drainage and foundations. The classes of roads and pavements at present requiring attention are earth and sand clay roads, gravel roads, broken stone roads, bituminous surfaces on gravel and broken stone roads, bituminous macadam pavements, bituminous concrete pavements, sheet-asphalt and asphalt-block pavements, wood-block pavements, stone-block pavements, brick pavements, and cement-concrete pavements. In connection with the above a thorough study of the materials of construction is essential, which include rocks, bricks, woods,

cements, concretes, and bituminous materials. Furthermore, such important subjects as street cleaning and snow removal; the relationship of the construction of car tracks and pipe systems, sidewalks, bridges and culverts to highways; and, finally, the comparison of the essential characteristics of roads and pavements and a consideration of economics, administration and legislation as applied to highway problems should be considered.

The civil engineering curricula of American universities may be considered as made up of three groups of subjects which may be classified under the captions; humanities, pure science and applied science. The scope of this brief introductory paper will not permit of a discussion of the relative values to be attached to each of the above groups. Fruitful discussion has already been presented relative to this basic educational problem. Conditions as they exist in our leading institutions will be taken as a criterion of the opinions held by those in control of the content of engineering courses. Attention will be rivetted upon those courses commonly designated under the caption, "applied science."

Applied Science Courses.

The applied science courses in any civil engineering curriculum may be considered under three general heads: Fundamental courses, such as certain work in mechanics, hydraulics, mechanical drawing, surveying, etc.; courses in the different branches of civil engineering, such as structural, railroad, highway, sanitary, hydraulic, irrigation and geodetic engineering; and courses in allied departments of engineering, such as mechanical, electrical, metallurgical, mining, and chemical engineering. For the purpose of this paper a discussion of the first and third classes is not necessarily pertinent. The discussion, therefore, will be confined to the applied science courses covering branches of civil engineering as defined by university divisions of engineering.

It is evident that there are certain subjects, such as struc-

tural engineering, to which more time should be devoted than to some other subjects due to the training secured in the application of fundamental principles of mechanics and the demand on the student for logical analysis of thought and the complete solution of problems demanding constant attention to the interrelationship of parts.

There are, however, a number of branches of engineering which do not come under this head but cover the application of accumulated knowledge of facts and the relationship between theory and practice as exemplified by experimental investigation and service tests. Such branches of civil engineering are railroad, highway, sanitary, hydraulic, and irrigation engineering. An examination of practically any civil engineering curriculum will effectually demonstrate to the skeptical that the division of the total amount of time devoted to the above branches of engineering has not been worked out upon a logical basis as represented by the status of the requirements of a general knowledge of the essentials of any one of the branches mentioned.

Highway Instruction in the C. E. Course.

It is obvious that to recommend that a specific amount of time should be devoted to the study of highway engineering as an integral part of all civil engineering curricula would be as unjustifiable as the practice of many laymen in seeking for a panacea in the form of one type of road or pavement to satisfy all traffic and local conditions. It is advocated, however, that as much time should be devoted to highway engineering as is now assigned to hydraulic or sanitary engineering, or to railroad engineering, after having deducted the periods devoted to curves, earthwork and surveys. If this plan is adopted, from three to six semester hours would be devoted to highway engineering. In addition a certain portion of the time devoted to higher surveying and railroad surveying could be profitably devoted to surveys of roads and streets. Furthermore from two to four afternoons of the course in the testing of materials could with beneficial results be assigned for

demonstration lecture laboratory work on the tests of the materials used in the construction of roads and pavements.

The problem presented is in reality one of scientific management of the civil engineering student's time in order to secure a product of highest efficiency considered from the standpoint of a broad training to equip him for entrance in any one of the numerous branches of civil engineering.

PROSPECTIVE OPPORTUNITIES FOR HIGHWAY ENGINEERS IN A NATIONAL HIGHWAYS DEPARTMENT.

BY CHARLES HENRY DAVIS,

President National Highways Association, Washington, D. C.

To begin at the end—the opportunities are unlimited! But why? We grew as a nation during the scientific growth of the world, so to speak. Prior to this period other and older nations had provided themselves with highways. Methods of intercommunication, up to the limits of apparent needs, are essential to the well-being of any people. People, like water, stagnate if confined to one locality. They must run and play, like the brook itself, or become sluggish and dull—to themselves as well as to others. Hence before the coming of steamboats, railroads, the printing-press, and electricity, roads were built by the older nations so that their peoples could move. Roads were the only means they had of intercommunication. But we came to be a nation when these modern methods of connection and communication were being perfected. As these means were more rapid and as our country was so large, their development pushed one side the building of roads. We were too busy for road-building and our need therefore was not then so apparent.

Magnitude of Expenditures for Roads.

But now we are, as a nation, awakening to the lack of our forethought, the pressing necessity and the vital importance of road-building. This is evidenced by some fifty major good roads or allied associations, five hundred state and local organizations, the same number or more automobile clubs, and some one hundred thousand road officials throughout the United

States. We are probably now spending directly and indirectly over $500,000,000 per annum on the roads of the country. And yet we have less than ten per cent. of our 2,300,000 miles improved—or with the semblance of improvement, such as it is. What will we spend to make them all good roads, and to maintain them? No one can tell. No one can foresee. But it is safe and conservative to predict an expenditure of over $1,000,000,000 per annum during the next twenty-five years, an investment exceeding that on our steam railroads. And then we shall only have made a beginning.

Highway Economics.

To carry conviction of the coming of this vast expenditure and the economic necessity therefor: It has been estimated that more than five billion tons of freight per annum pass over our highways. Of this more than half would probably go over a system of national highways. It is estimated that the present average haul is a little under ten miles and that the cost is about twenty-three cents per ton-mile. This cost should not exceed eight cents per mile on a good road. In other words, at least one dollar and a half should be saved on every ton moved on our highways. Thus the total saving from good roads staggers the imagination. Our railroads carry two billion tons of freight per annum. If, instead of the above estimate, we assume that only an equivalent tonnage passes over our highways, then the saving per annum would be $3,-000,000,000 on a system of good roads. The probabilities are that the saving would be far greater.

The value of farm real estate and buildings is $35,000,000,-000 for the United States. Two million miles of improved highways will increase land values some $10,000,000,000, an increase of approximately one-third above present values. Does this indicate we cannot afford to improve all our roads? There are 6,500,000 farms. This means that the average increase of value for each farm would be $1,500. At $100 a year per farm we would have a sum of $650,000,000 per annum with which to improve our highways. This would build 130,-

000 miles a year at $5,000 per mile, or in less than twenty years all of our highways could be improved. In this time they would many times pay for themselves in savings and also in increased land values.

Such figures could be multiplied. It is therefore beyond any reasonable doubt that the nation will spend the money needed to produce such magnificent returns in both usefulness and economy.

Bad Roads and Illiteracy.

But there is another side of even greater importance,—civic, moral, and educational,—which far transcends the material and commercial part of the problem. We cannot have good schools in the rural districts without good roads. And we must have good schools.

The relation of good and bad roads to illiteracy is indicated by the following table:

	Native White of Native Parentage / Total Population (1910).	Per Cent. Improved Roads (1909).	Per Cent. of Illiterate Native Whites of Native Parentage (1910).		
			Total.	Urban.	Rural.
New England: Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut	2,135,801 / 6,552,681	22.2	0.7	0.5	1.2
South Atlantic: Delaware, Maryland, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida	5,397,864 / 12,194,895	6.7	8.0	2.2	9.8
Pacific: Washington, Oregon, California	1,684,658 / 4,192,304	14.2	0.4	0.3	0.6
West South Central: Arkansas, Louisiana, Oklahoma, Texas	4,101,510 / 8,784,534	2.6	5.6	1.4	6.8

This table does not of course include foreign born, native

born of foreign parentage, or negroes, all of which are excluded for obvious reasons. Illiteracy is eleven times greater in the South Atlantic States than in New England, while the percentage of improved roads (such as they are) is less than one-third. Similar figures for the Pacific and West South Central States show fourteen times greater illiteracy, while the percentage of improved roads is less than one-fifth as much. The increase in illiteracy in rural New England is only one hundred and forty per cent. above the urban population, while in the South Atlantic States this increase is nearly three hundred and fifty per cent., due to the lower percentage of improved roads. This difference is slightly greater in comparing the other two groups in the table.

The children of to-day are the electors, the representatives, the senators, the judges, one of them the president, of to-morrow. The population is increasing by leaps and bounds. If education means liberty, and if poor roads mean illiteracy or worse, have we a right *not* to build good roads, even if they would not pay for themselves well within the generation which builds them?

And of equal importance, our people cannot get "back to the land" unless we have good roads. They must get back for us to live as a nation!

Opportunities for the Highway Engineer.

The evidence is therefore overwhelming that greater sums are to be spent on the roads of the United States, within the next generation, than on any other activity of the body politic. They will be used by all. They will be paid for by every one of us. They will be free to all of us. They will be of untold, daily advantage to us.

All this being true, is it not apparent that the opportunities are unlimited? In being unlimited they have a serious side! Will all the educational institutions, including the national government, be able to educate highway engineers rapidly enough to supply the need therefor? We think not. De-

cidedly not! Therefore the greater the facilities offered for such education the better for good roads, whether these facilities be private or public, state or national. We cannot obtain, in time for our needs, the education and therefore the knowledge that we need to properly and economically build the good roads of the coming generation. The opportunities for the highway engineers are therefore unlimited in or out of a national highways department.

OPPORTUNITIES FOR HIGHWAY ENGINEERS IN MUNICIPAL WORK.

BY GEO. W. TILLSON,

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A few years ago the author was criticized for the statement that the municipal engineer was behind his associates because he had not been able to produce a pavement that was entirely satisfactory. He still believes, however, that the original statement is true. This being the case, it follows that the perfect pavement has not yet arrived, and also that there are great opportunities for the highway engineer in municipal work. The question then seems to be: How can he best make use of these opportunities? In order to produce the best results he must thoroughly understand the properties of the different materials used in street construction, how they can be combined satisfactorily, and how to use these combinations after they have been made. While this statement comprises but a few words, the carrying out of the ideas involves a large amount of intelligent and patient study.

Pavement construction is a science. The situation is very different from what it was even a few years ago. The advent of the automobile for business as well as pleasure use is responsible for this. An automobile weighing from two to three tons and moving with a speed of thirty or forty miles an hour requires a very different type of pavement than a carriage driven at the rate of ten miles an hour. The same is also true of heavily-loaded trucks.

Examples of Paving Problems.

There is probably no one material used more in the construction of roads and pavements at the present time than

bitumen in its different forms. The engineer, then, through a competent chemist (as he will probably not have time to do it himself, even if he has the ability), should make himself conversant with all the different bitumens that are put upon the market. He should know all the different properties of each, bad as well as good. He should have experiments made to determine the resultant of certain mixtures so as to counteract, if possible, the defects of one by the good qualities of another. He must ascertain also if his compound is stable, and will not be too seriously or too quickly damaged by oxidation or other natural causes. He should know the defects of the present pavements, and study to perfect his materials so that these defects will be corrected in the finished product.

Take granite, for instance. It is well known that this makes a very durable pavement. It is noisy, however, and often wears unevenly, so that on many streets it is very objectionable. A study should be made of the manufacture of the blocks with a view of having them of such a size, shape and character that the objections will be reduced to a minimum. The method of laying is also important as both of the above objections can be materially reduced by special methods of laying, attention being given to the size of the joints and the proper material for filling them, as well as the quality and depth of the material in which the blocks are imbedded. These are both important factors in overcoming the defects mentioned.

But there is probably more necessity for investigation in the case of wood pavements than in that of any other kind. The questions involved relate to the character of the wood, the method of, and material for treatment, as well as the method of laying. The most mooted point is the character of the preservative. This refers both to its origin and specific gravity. The principal objection to wood pavements at the present time is their slipperiness, and it is probable that this defect might be materially reduced by careful study and reflection.

But the engineer should not be satisfied with the pavements

now in use. His knowledge should be such as to suggest possible combinations of nature's wonderful variety of materials, so that a new and more satisfactory pavement might be evolved, and so that all materials, whether in an original or combined state, could be used to their best advantage.

Selection of Paving Materials.

But even when the engineer has learned all about the different materials and the results of their combinations his troubles are not over, for he then comes to the final test of application, that is, the paving of the streets with the materials best adapted to them. The problem is not a simple one. The engineer will find that the different interests desire different materials. For instance, the people residing or doing business on a street wish a smooth, quiet pavement and one that is easily cleaned, and care not how it affects traffic. The team owners, on the other hand, wish a pavement that offers slight resistance to traffic and is not slippery. They have no concern whatever for the noise caused by the vehicles. Then, too, the determination of the officials themselves may often differ from that of either of the above interested parties. To harmonize these different demands, even after a careful study has been made of the materials, is not a simple matter.

The first duty of the official is to determine what material should be used upon a street from an economic and utilitarian standpoint. As a rule, pavement determinations in this country have been made by rule of thumb rather than from a study of scientific conditions. An asphalt pavement has been taken to be an asphalt pavement, and a stone-block pavement a stone-block pavement, and these have been laid upon different streets without any definite idea of traffic. When an architect is about to design a building it is absolutely necessary for him to know what properties the building is required to have and to what extent it is to be used. The municipal engineer almost never has any data of this kind as regards street pavements. Engineers in different cities talk of heavy, medium and light traffic, but they have no idea what these terms mean, as they

are simply comparative and not absolute. It is undoubtedly possible to go into any city of this country of over two hundred and fifty thousand inhabitants and hear it said that a certain intersection has more traffic than any other intersection in the country except some in New York. New York is generally excepted, especially if the visitor happens to be a New York man. The borough engineer of Fulham, London, has worked out a formula, deduced from the time certain wood pavements have lasted under traffic, by which he estimates the life of any wood pavement under any given traffic. This would probably be quite accurate if the word "traffic" were more definite. In this country little attempt has ever been made to take any traffic census. The Boroughs of Manhattan and Brooklyn, New York City, have, however, done something along this line during the past few years, and it is hoped that the practice will be continued and extended to other cities.

The writer has, however, seen no well-established and defined unit of traffic. The values of the different fuels are rated in British thermal units, and it seems as if a scheme similar to this might be worked out for traffic. It is not sufficient to say that a certain pavement has so many tons of traffic per yard per year, as it can be easily understood that the passage of one truck weighing ten tons, with steel tires, over a pavement at a rate of four miles per hour, will have a very different effect on the pavement from ten different vehicles weighing one ton each, equipped with rubber tires and moving at different velocities.

A Traffic Unit.

What is necessary is to find by experiment the relation of the different kinds of traffic to a standard traffic unit. If such unit should be considered, for example, as a two-ton load, on four wheels with steel tires, passing over a pavement at the rate of four miles per hour, then all other vehicles, either heavier or lighter, could be measured by such unit. By experimenting with standard apparatus, the effect upon different

pavements of different loads, at different speeds, with different tires, could be ascertained, and in such a way all traffic could be reduced to the standard unit, so that when traffic of a street is spoken of it would be given in units, as, say, 1,000 traffic units. This unit should relate to certain widths of pavement.

The writer appreciates fully that it would not be a simple proposition to work out exact traffic conditions, even after the foregoing results have been obtained, as the observer must rate vehicles according to his judgment, which could not be absolutely accurate, but it would undoubtedly average pretty nearly correct in the long run, and it would be very much more nearly correct than anything that is being used at the present time.

CONCLUSION.

The writer feels, therefore, that there are open to the highway engineer in municipal work opportunities for determining not only the properties of paving materials, both simple and compound, but also their application; and that if his studies should result in simplifying the questions somewhat along the lines suggested herein, there would be a great advance in the paving art, in the laying of pavements, as well as their selection, for certain given streets could be paved according to scientific principles.

OPPORTUNITIES FOR HIGHWAY ENGINEERS IN CONTRACTORS' ORGANIZATIONS.

BY H. B. PULLAR,

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The recent rapid development of paving and road-building has opened up a new demand for engineers, and this new demand must be filled by engineers trained along new and specific lines. Until recently a general civil engineering course amply prepared an engineer with sufficient knowledge to take care of any general road or paving work which might come under his supervision, but in this day of specialization it is necessary that engineers entering this new field be more carefully prepared to successfully meet and solve the numerous and varied paving problems and to direct to the best advantage the expenditure of the enormous funds now being appropriated for good roads and pavements.

Formerly an engineer desiring to specialize in road and pavement construction was limited in his field of endeavor to accepting positions with the state, county or city, or to acting as a consulting engineer to public officials having charge of paving and road work. To-day there is a much broader field and one in which the opportunities for advancement and the compensation are much greater than they were even a few years ago. This field is the up-to-date contractor's organization. There is a distinct and urgent demand for good highway engineers in contractors' organizations, and the day does not seem to be far distant when public officials will demand that work be given only to contractors having capable and efficient organizations, which necessarily must include highway engineers.

Contractors Need Engineers.

Practically up to the present time there has never been a demand for highway engineers by contractors, because there were only a few different standard types of pavements and the contractors were familiar with the classes of construction they bid upon and did not attempt to enter into other fields. To-day the problem is entirely different, and in place of the few standard types of pavements and roads there are numerous and varied types which call for different construction.

In nearly every case where contractors to-day wish to bid on paving construction they are confronted with specifications calling for numerous different types of construction. They have not always been educated in the proper method of laying these different classes of pavements, but are usually willing to take a chance. The result has been that there have been many failures, which have been due to improper handling of materials and improper construction, but which have been unjustly laid to the new type of pavement or road. As is always the case when any industry is rapidly developing, there are also many new types of paving, both patented and otherwise, which are continually being brought into the market, some of which will undoubtedly prove successful. The majority, however, will soon be discarded as being unsuccessful and unsatisfactory.

What a Highway Engineer Can do for a Contractor.

With the advent of the highway engineer in the contractor's organization a large percentage of failures will be eliminated, for if he is properly trained he will be versed in the different types of construction and will be able to get the best results with the materials with which he must work. He will be able to advise and assist the contractor in developing new and more up-to-date construction, and guard him against taking too many chances. He will, from his training, more carefully look after the details of construction, such as drainage, grades, fills and crowns of the finished roadway, all of which at the

present time are given too little consideration by contractors. In case of apparent failure of the work his training will teach him to look for the real cause and not to blame, haphazard, the new type of construction or the binding material, as has too often been done.

It does not cost a contractor any more to lay high-grade, first-class work than it does to put in careless and unsatisfactory work; in fact the cost of inefficiency and carelessness in running a great many of the contractor's plants throughout the country would more than offset the cost of turning out uniform and high-grade pavements. The properly-trained highway engineer will see these different points and by actual demonstration show the contractor where he can lower his maintenance cost and at the same time give better satisfaction to the officials and property owners. By his work he will eventually be a big factor in eliminating the now too well recognized combination of politics and graft in paving and roadway construction. Already a number of the most successful and prominent contractors in the country are employing men trained in highway construction and have found it both wise and economical to have these men in their organization to pass upon and keep uniform all details of construction which have heretofore been left to the superintendent and plant foreman.

There is another potent reason why contractors will require the services of highway engineers, namely the fact that, on account of the severe competition and rapid development of the road and paving industry, materials companies are continually putting out new products and changing the old. It is only fair to state that most of these materials companies are doing their utmost to turn out the best possible material for the money. They are, without question, giving valuable coöperation to engineers and chemists in order to get the most suitable materials for the different types of construction and are continually studying and overcoming the problems of paving and road-building. However, even in view of these facts it is a big advantage for any contractor to have in his organization a highway engineer who will study the different

traffic, climatic and other conditions under which the pavement or road will be subjected, and then be able to judge those materials which are most likely to prove suitable for the work. He will also be able to advise regarding the proper handling of these different materials, or at least to look for and properly receive expert advice regarding them. There are few bituminous materials on the market to-day that require the same treatment at the plant in order to get the best results at the lowest possible cost; in fact numerous failures can be cited where the cause was due to the handling of different materials at the paving plant in the same manner.

The Engineer Must Make Himself Useful.

While the highway engineers in the contractor's organization will likely find his work for some time confined to estimating and to the actual construction, he will in time prove a valuable asset in the promotion work. If he is able to clearly and concisely place the merits of his contractor's proposition before interested public officials he should have no trouble in eventually replacing the present day "good-fellow promotor" whose knowledge of the industry is usually confined to a few facts given to him by the contractor and materials companies, and whose biggest assets are a friendly smile and the ability to attractively present his proposition.

There will be many obstacles to overcome by the highway engineer entering a contractor's organization. He will have to proceed with his new ideas and methods in a slow but sure way and use his technical knowledge in a practical and efficient manner, but if he is trained by such a graduate course as that given in highway engineering in Columbia University he cannot help but be of value to the contractor, and will find each year an increased demand for his services. It would be well if universities and engineering colleges would consider the advisability of incorporating a three-hour course for one year devoted to highway engineering in their undergraduate courses in civil engineering in order that engineering graduates might have a broad general knowledge of the field of highway engineering.

OPPORTUNITIES FOR HIGHWAY ENGINEERS IN MANUFACTURING CONCERNS.

BY W. H. KERSHAW,

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The opportunities for highway engineers in manufacturing concerns are many. The recent increased activity in highway construction has opened up a vast market for many of the largest materials and machinery manufacturers, concerns that have for years been engaged in other fields and are well manned with officers and engineers thoroughly acquainted with the needs of the other branches of the business.

A concern that intends to aggressively enter the newly-developed highway field must add to its organization engineers especially trained in highway work. As a concern's ultimate success depends upon the true value of its products it is necessary to see that these products are continually improved and brought nearer to perfection. Changes recommended as a result of laboratory or factory tests must be correlated, by an engineer familiar with highway work, with the results accomplished in actual practice. In this way only is it possible to obtain competent approval of changes that have merit and discard quickly those changes that would in the end result in failure.

Advantages of the Manufacturing Field.

The need of such engineering service is generally recognized by manufacturing concerns and such positions offer employment for highway engineers at attractive salaries. These positions possess one great advantage over municipal and state highway engineering work, namely, in point of permanence

and the possibility of sure and consistent increases in salary dependent on the length of service and increased responsibility. As a step toward an independent consulting practice of a highway engineer in the field of active construction, either with a contracting organization or with municipal or state government, a position with a manufacturing concern actively engaged in highway work deserves the consideration of the engineer. The traveling generally necessary to a greater or less degree, with highway engineers connected with manufacturing concerns, assures a large acquaintance with the most successful engineers that are engaged in highway work. Traveling also enables them to correctly judge what the relative merits of the various materials and methods are, a correct determination of which is practically impossible to an engineer who is forced to base his decisions on the results of practice in a limited section.

There are chances for highway engineers not only in the engineering departments of manufacturing concerns but also in the manufacturing and sales organizations. The opportunity for engineers in sales organizations, dealing with products bought under engineers' specifications, has always been recognized, as well as the fact that it is difficult to obtain engineers that are able to sell.

Engineers Needed in Sales Work.

The general trend toward increased efficiency in the engineering organizations of cities and states requires a change in the sales and promotion methods used in selling material and equipment. The ability to correctly determine causes for success and failure and accurately report on the service tests to which their own material has been subjected requires either an engineering training, on the part of the salesman, or that the salesman be given engineering assistance.

An idea of the great number of manufacturing concerns requiring the services of engineers can best be obtained by noticing in any current engineering paper, devoted entirely or largely to road work, the number of manufacturing con-

cerns that are active in highway work. Numbered among these are the oil, tar, and asphalt companies, stone quarries, brick manufacturers, wood and asphalt-block concerns, and manufacturers of by-products used for construction in binding roads, together with hundreds of machinery concerns and sales organizations manufacturing and dealing in road-building equipment.

OPPORTUNITIES FOR HIGHWAY ENGINEERS IN THE SOUTHERN STATES.

BY ROBERT J. POTTS,

Professor of Highway Engineering, A. & M. College of Texas.

Viewed in a general way it may be said that the South is considerably behind the North, and, more particularly, the East in both the quality and amount of road improvement. This condition may be attributed to three principal causes. The first and most important is the generally impoverished condition of the country after the Civil War, its backwardness in development since that time, and the consequent small taxable values. The second cause is the very general lack of really good materials for road building throughout a large part of the South. The third cause of our inferior roads is the lack of competent engineers to handle the work and the attendant lack of an educated public opinion which will demand first class work in all cases.

This lack of high grade roads in the South is by no means universal. Where the wealth of the community will justify the expense, many excellent county road systems have been built. This is especially true where good material is available. For instance, few counties in America have better or more modern roads than Fulton County, Georgia, in which the city of Atlanta is situated. With an abundance of excellent rock, adequate taxable values and a large supply of convict labor, they have constructed a large mileage of macadam and asphalt-macadam road that will compare favorably with the best in the country. Many other notable exceptions to the general rule could be mentioned, which show very satisfactory progress in road improvement where local conditions will justify.

Status of Highway Construction.

Of the states usually included by the term southern, only Virginia, West Virginia, Alabama, Louisiana, and Kentucky have

regularly organized state highway departments. North Carolina, through its geological and economic survey, is rendering practically the same service to the state as is given by the highway departments of the other five states. We may therefore consider that six southern states have initiated the policy of state supervision of public-road building. It is hardly worth while setting out the powers and duties of these state highway departments. Suffice it to say that they are much more limited in their operations than are similar departments in the eastern states. This is caused by lack of funds, lack of legal authority, and lack of a strong public sentiment in favor of centralizing road control instead of allowing it to remain a local question as heretofore. However, a start has been made and these departments will doubtless be strengthened from time to time until they become adequate to direct all road work in their respective states. The greater number of the remaining states in the South have, through their state schools or otherwise, done at least something towards furnishing engineering advice on road work. These states will doubtless soon follow the lead of the six states mentioned above by actively taking hold of the public road problem and directing future construction.

Control of Expenditures for Highways.

The employment of county engineers has been relatively as much neglected as the creating of state highway departments. It is the exceptional county where an engineer is regularly employed from one year's end to the other. In the larger counties, particularly those having large towns or cities, the annual expenditures for road improvement are seldom less than $50,000, frequently two or three times that amount. The usual rule in such counties is to have a county engineer who prepares plans and supervises all work, though actual legal control of the work is still vested in the county commissioners. In the great majority of counties in Texas the regular annual income is less than $50,000, and the whole matter of road improvement in each county rests with the county judge and four

commissioners, who constitute the county commissioners' court. If a bond issue for road improvement is authorized by the voters of a county or a district, an engineer is employed to plan and supervise the construction of the roads. Payment for such engineering service is made either as a percentage fee based on the cost of the work or by a stipulated salary.

Prospects for Development.

The solution of the road problem of the South and its successful execution can therefore be said to lie more largely in the future than that of any other section of the country. Herein lies the opportunity of the highway engineer in the South. In a productive country, high-grade roads are a necessity; and that same productiveness which makes roads necessary, gives ample assurance of the ability to pay for them. This is the situation in the South today.

The general improvement of the country is pushing the road question to the front. Southern counties in large numbers are issuing bonds for good roads every month. It is very important that the taxpayers get a dollar's worth of road for each dollar expended. Roads must be built so well that they will give service, and at the same time not be prohibitive in cost. In many sections of the South the engineer is at once confronted with the fact that he *must* build a road of material that would be quickly rejected under the standard specifications of other states. It therefore becomes necessary to so adapt his materials, and so regulate the character of workmanship and the consequent cost of the road that its serviceableness will be commensurate with its cost.

Much progress has already been made in the coastal region of the southern states and in the Mississippi Valley towards adapting local materials to road construction, but much more remains to be done. There is opportunity for every engineering college in the South to render valuable service to its state by a study of these problems. There is still greater opportunity for every practicing highway engineer in the South to thus aid in the development of his country and thereby put his own future success beyond all serious question.

ESSENTIAL QUALIFICATIONS OF HIGHWAY ENGINEERS.

BY HAROLD PARKER,

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Before a person is qualified to design, construct, or maintain a road or highway, it is fundamentally necessary that he must have had experience in the actual construction, however great his technical attainments may have been. No technically-educated engineer, however complete his theoretical training, is fit to design or construct a road or to take charge of its maintenance, unless he has also gone through the purifying fire of actual continuing experience. This fact must be recognized by all persons who have long been engaged in the building of roads, and must be distinguished from the necessary qualifications of a bridge builder or even an engineer whose profession is that of railroad construction.

It is conceivable that a successful road-builder may never have received any technical education whatever. He may, by constitution, by the character of his experience, and the clearness of his observations, be able to build and even take care of a given road. But, in such event, his skill and success would be limited wholly by his actual experience.

Experience Essential to Success.

It is intended to convey the conclusion, therefore, by what has been just stated, that a highway engineer, to be properly equipped for the successful practice of his profession, must have, in addition to his technical knowledge, a general and detailed experience in the field. In short, a successful road-builder must have both the technical education which comprises the knowledge of the purely engineering features, in-

cluding the character of materials and the study of economic organization, but he must have as well (and it is of equal if not greater importance) experience in the actual work, controlled by careful observation and study of the operation of his forces in the field. It is unnecessary, perhaps, to point out how bad and often disastrous are the results of placing persons in charge of the work of construction or the inspection of methods and material, who have only their technical schooling as a guide. The essential qualifications of the highway engineer combine two primary requisites—the technical and the practical—but other than this it is necessary that to be successful in the practice of the profession of road building, the engineer must possess the power of controlling men and of directing them in their work without friction, in order to secure the best results. He must in character be an observer of everything that is going on around him which tends to the successful operation of what he has undertaken. He must have the qualities of a topographer, and must realize by experience and training the character of the soil over which his road is to be constructed. He must possess that instinctive quality which indicates to him which is the best line for any change in location, if he is following the line of an old road, or where best to place it, if he is building a new one. These qualities are not to be found in many men, but many men do not become famous road-builders, and in selecting the qualifications it is necessary to take the ideal, though only a few can ever attain eminence.

Equipment of the Highway Engineer.

It is of course desirable that the young road engineer should be encouraged to believe that he may be the one to attain eminence, for without such hope and ambition he will be little else than a drudge who performs his daily task with just enough effort to secure his daily stipend. To be a real road expert, he must put to practical use such parts of his school training and acquirements as are pertinent to his work. He must study the topographical conditions of the road he is con-

structing or reconstructing in order to determine the method of drainage, the sizes of the culverts and bridges, and the escape of water collected by the roadside. To that extent he must be a topographer. He must have knowledge of geological conditions in order to determine the type of foundation under the road itself, if any is necessary, and decide whether local rock is of a quality good enough to be employed in construction, or the sand can properly be used in making cement concrete.

He must be enough of a chemist to know what the characteristics of the various forms of bitumen for road surfacing should be in order to best supply the needs of the particular road he is designing. He should understand how Portland cement is made and how it should be tested. He should understand the method of testing all materials entering into the construction of a road. It should be realized, however, that a road engineer need not be a chemist, a geologist, or an expert tester. Each of these is a profession of itself, and it will inevitably detract from his success if he undertakes to assume the part of a specialist in an occupation that requires undivided attention. The man who has these acquirements, both technical and practical, may become a great road-builder, provided that he has, in addition, the tact to live in harmony with his associates and the skill to manage men successfully.

The modern road-builder is a much more complex product than his prototype of the past. Macadam had only to apply good sense to scientific principles in order to design what was the standard of road construction up to the period when the automobile revolutionized highway construction. The steadily growing use of motors and their high rate of speed has destroyed all previous theories and methods, and has emphasized the necessity that the road engineer must have the scientific training which has been dwelt on in this paper, for he must be able, in making the design for any proposed road, to forecast the amount and kind of traffic which will result from improving one out of several routes, and thereby concentrating travel on the one improved; as well as to provide

for the disintegrating action of driving wheels under heavy or swiftly-moving loads.

The demand for properly educated and trained road engineers is far greater than the supply. Many men who are doing the work are totally unequal to it. States and municipalities are rapidly coming to a realization that incompetence is an expensive indulgence in their engineers or superintendents, and they insist more and more strenuously on having only those whose qualifications meet modern needs. It cannot, therefore, be too earnestly impressed on the prospective road engineer that his education must be as exhaustive and thorough as possible, and that without a technical training he must be handicapped and retarded in his progress toward ultimate success.

SHORT WINTER COURSES IN HIGHWAY ENGINEERING.

BY C. E. SHERMAN,

Professor of Civil Engineering, The Ohio State University.

Probably the title assigned above at present stands for considerable confusion in the minds of engineering educators and others over the country, and therefore it will relate here chiefly to the course given from Monday, February 24, to Saturday, March 8, 1913, both dates inclusive, at The Ohio State University, in accordance with the program printed below. Detailed information of the short winter courses lately inaugurated at the University of Missouri, at Columbia, and at Kentucky State University, and at other schools, is not at hand, and so for this reason also we will limit the following description, together with succeeding comments and suggestions, chiefly to the course recently given at Columbus.

The graduate course in highway engineering at Columbia University at which attendance for two winter terms, each extending from December first to April first, is required for a Master's degree, was established only December 1, 1911; and the shorter course in highway engineering at that school was begun only last year. The course given last winter at Ohio State was our first experience. So it seems that such winter courses are of very recent origin, too recent perhaps to see their value clearly, or to make comments and suggestions of permanent value at this time.

Our two-weeks session was made possible by the generosity of the Ohio Good Roads Federation, which in October, 1912, gave $500 toward establishing such a course, which sum covered the entire expense of administering the program above set forth. It was given under the joint auspices of the State Highway Department and the department of civil engineering

of the university, the officers from both departments, and a number of other lecturers, giving their services free.

Objects of the Course.

One object was to disseminate information among highway contractors, inspectors, county engineers, and commissioners, and all others interested in bettering the highways of the Commonwealth. To reach these people after some press notices had been sent to the Ohio newspapers, 3,000 twenty-four-page bulletins 5 by 8 inches in size containing five full-page cuts and complete program were printed and copies mailed to the following:

600 to newspapers of Ohio.
90 to newspapers outside of Ohio.
190 to county surveyors and city engineers.
450 to contractors, inspectors, and county officials.
190 to county surveyors outside of Ohio.
20 to college newspapers.
600 to Ohio Good Roads Federation.
200 to State Highway Department.
5 copies to each of the speakers—various good-roads magazines and roads organizations were included.
250 to the University Faculty.

About 450 of the above names of road builders, contractors, and inspectors were secured from the files of the State Highway Commissioner. Five thousand bulletins in all would have been a better edition. A list of good-roads associations numbering 486, which can be obtained from the U. S. Office of Public Roads, together with lists of good-roads publications and those occasionally printing articles on highways, might have been used to a greater extent than they were.

As it was, from the circularizing and advertising done, the attendance was as given below.

These attendants were distributed geographically as follows: Franklin County, 31 registered students, Darke County 6, Knox County 5, Miami County 4, Hardin and Meigs 3 each, Clinton, Scioto, Wayne, Noble, Muskingum, Delaware

2 each, Clarke, Columbiana, Champaign, Fairfield, Guernsey, Lorain, Lucas, Highland 1 each.

Civil Engineers	22
Highway Engineers	9
County Surveyors	8
City Engineers	4
County Commissioners	3
Road Inspectors	5
Street Paving Engineers and Superintendents	4
Contractors	8
Materials Men	6
General	7
Farmers	2
	78
Counted twice	2
Total	76

Another object of the course was to establish a clearing house where the ideas of engineers, constructing contractors, teachers, county surveyors and commissioners, and material men could be exchanged, and where questions and discussions could be freely indulged in. To gain this end the program was arranged so that one hour of discussion followed nearly every paper, and this program was adhered to excepting that in three or four instances the lectures lasted longer than one hour, and excepting that on Friday of the last week so many material men spoke that little time was left for discussion. The last Friday of the session was reserved for these material men to present the merits of their respective wares, and this open court proved to be a valuable part of the program.

Still another object of the course, and this doubtless was one of the first in the minds of the officials of the Good Roads Federation, was to arouse public interest in legislation for better highways in the State, which was pending in the Legislature while the highway course was in session. This interest was further aroused by a "Rural Life and Good Roads Congress" organized by the members of the Federation with the assistance of Governor Cox, and held in the city on Wednesday and Thursday following the close of the highway course.

Highway Legislation in Ohio.

Just how far the two gatherings effected the last object is hard to say, but the net result of legislation in highway matters when the Legislature adjourned on April 28, was a great step in advance. A proposed amendment to the State constitution authorizing the issuance of bonds for $50,000,000, to be expended on highways during the next ten years, had been defeated at the polls last November. The new law now will provide about two thirds of that amount within the same period, to be paid out of general revenues from state taxes. Also a comprehensive scheme for the future improvement of main market roads and intercounty highways, which had been carefully worked up by the State Highway Commissioner, was adopted, while another law still provided for an extensive codification and revision of the laws relating to administering highways in the State.

The same Legislature appropriated $1,000 to the University for a short winter course in highway engineering to be given in 1914, after disallowing $10,000 for inaugurating extension work in highway engineering. This last asking was supported by the state highway officials that it might relieve them of doing lecture work at institutes as required by a previous law, but the demands for money due to recent flood disasters caused the amount to be stricken from the appropriation bill.

Administration of the Course.

Some details of administering the foregoing short course were as follows: No entrance requirements were stipulated, no text-books were required, and no fees were charged except one dollar for registration, upon payment of which a decorated button was pinned to coat lapel and used for admitting bearer to any lecture or demonstration in the course. The lectures were given on the college grounds in various rooms where blackboards, lanterns, a moving picture machine, and the state highway and other university laboratories were available. While the audiences were heterogeneous so far as

preparation was concerned, it was found possible to proceed in fairly logical sequence from fundamentals to debatables, and from subsoils or foundations of roads through surfaces, surface treatment, to maintenance and subsequent administration and legislation. Blue printed diagrams or mimeographed syllabi were passed to each student at a few of the lectures, but no text-books or reference books were required to be read.

Attendance at the lectures ranged from 30 to 150; the more popular ones were thrown open to the public. The seniors in civil engineering were excused from other work in that department to hear all the lectures in the highway course that they could. Likewise, the junior civils, who were studying roads and streets in our regular course for a civil engineering degree, were excused to hear the more important lectures. Inspection trips were made on one day to the two state experimental highways, one containing 17 varieties built four years ago, another 22 kinds built last year. On another day the city asphalt plant, city streets, and several quarries and gravel supply works, all near at hand, were visited. The laboratory sessions consisted of demonstrations in the cement and concrete laboratory on one day, and in the highway laboratory on bituminous and other materials on another. No examinations were held at the conclusion of the course, and no certificates were granted.

Needs in Highway Instruction in Ohio.

Ohio with 88 counties totaling 41,240 square miles of area (41,100 of it land), had 88,861 miles of roads outside of incorporated towns according to the scaling from the carefully prepared State Highway Atlas, December, 1909. Of this amount, speaking roughly, about 9,000 miles constitutes the main market roads and inter-county highway system recently legislated upon, while nine times this amount or about 80,000 miles will necessarily always remain of minor importance.

While experience is too brief to warrant extensive convictions, the writer thinks that there is much more urgent need for extension work than for short winter courses in high-

way engineering in Ohio and elsewhere, and that the former would be far more effective. It will not be so hard to get proper superintendence for constructing and maintaining the 9,000 miles of main highways as to similarly handle the 80,000 miles of secondary roads. If the latter situation were well in hand it would be far easier to remedy the weak spot in our American highway situation touched upon in the closing paragraph of this article. It is doubtful whether more than half of the civil engineers of the country yet fully comprehend the subject of drainage, and it is certain that the general public does not. It will be far more difficult to reach the general public by inviting it to the university to hear lectures on such fundamentals, than to carry "war into the territory of the enemy" by specially-equipped instruction trains run into every part of the State, similar to or in connection with agricultural extension work.

However, the whole matter is one of education, and short winter courses in highway engineering are a means to this end. They should not be neglected, because they may become sources of inspiration, and effective centers for promulgating sane ideas in road construction. Attendance at our short course last winter, though small, was enthusiastic. The future development of such courses will be watched with interest.

As to advanced or postgraduate courses in highway engineering, the writer believes that a regular four-year course in civil engineering, as such courses are now given in most of the engineering schools of the country, should precede such advanced work. Such a regular or general course affords none too broad a foundation for the person who intends to specialize in highway engineering.

Outlook for Highway Engineers.

The outlook in America for such specialists is disheartening at present, for our various commonwealths, counties, and municipalities, do not accord to such talent, nor to the engineering profession in general, the consideration it deserves. A propagandist is as likely to be placed in charge of public

works as a quieter trained student of economics and engineering who is at the same time a good executive. The material men in some localities at present, unwittingly or not, seem to be fostering this attitude of the public mind. One wonders how long some of our cities, counties, and even larger political communities, will continue to allow men with little or no engineering training to administer their public works, and obtain an education at the expense of the community by running the gamut of mistakes which a college course in engineering would lay bare.

THE HUMAN ELEMENT IN THE EDUCATION OF HIGHWAY ENGINEERS.

BY E. STAGG WHITIN,

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The road engineer cannot be said to have a complete education in road material if he is lacking in the knowledge of "the stuff that men are made of." Human clay is a basic requirement in road construction; its mixture with the oil of human kindness follows natural laws of the most primitive character, yet this formula seems to be lacking in the text-books and left for the graduate of the courses to derive somehow from the mystical letters "Q. E. D.," which haunt him night and day. Yet no patent is claimed, or even applied for; the secret process seems to be tied up somewhere in the heart of man along with the record book of our old friend Abou ben Adhem. Why not give the student a glimpse inside?

THE ROAD LABORER.

The labor problem as outlined in books on economics has been shunned by the student of road engineering with a feeling that it was foreign to his problems. Unionism, the struggle of factory groups, the demands of the labor leader, the restrictions of labor legislation, never seem to reach in any helpful way the laborers with whom the road engineer has to deal, but always seem to be an obstructing force affecting in some unhappy way the cost of materials and the time of delivery. The road worker has not seemed a part of this labor problem but just a real human being, a necessary element in human nature which just existed, apparently coming from nowhere and going to nowhere, unless it be to the proverbial

lower regions. Hit or miss, taken at random, each a problem in himself, changing from day to day, who could study in college anything that would be helpful in understanding him? Who would bother to classify him? Thus the "academic" has passed him by and with the failure to analyze has come the inevitable failure to utilize the by-products.

Convict and Other Road Labor.

Road labor is itself a by-product and has its own by-products. In road construction, either the surplus time of the farmer or the surplus labor of the farming community is made available in settled districts; in the more sparsely-settled regions the wage attracts the roving laborer, the track-walker, the young adventurer, the youth with a *wanderlust,* the summer vacation lad, and a few seasoned woodsmen. The uncertainty of this labor, the failure to be sure of it when making contracts, has created a demand for the use of the permanent slave-class of convicts, similar to those used in the Roman days. The demand has been met with no little favor as a possible solution of the prison problems, and at the same time has opened up a whole new type of development in the methods of handling road labor. The demand has necessitated the study and comparison of free labor with the labor of convicts, the relative efficiency of each and the comparison of methods for producing this efficiency in each group. The results as yet are meager, yet the introduction of the newer phases of cost-accounting and motion study promise before long some really scientific data; but the moral for the purpose of this paper must suffice in the pointing out that the movement for convict labor on the roads which is sweeping the country, being discussed in the platforms of parties, in the messages of governors, in the acts of legislatures, is forcing a new and constructive element into road engineering, and is forcing upon the colleges, which train in this line, a recognition of the human element in the problem of road construction.

The Road Camp as a Moral Force.

Road labor, whether convict or free, seems to be derived from the misfits in the general industrial life of the community, and has proven to be a valuable by-product; but the road work in itself is not without value in the production of a new element aside from the road and the wages paid. It is a training school for bad and good from which the participants graduate the stronger and better, the weaker or more degenerate, in proportion as the life of the road camp and the methods used in a day's labor, tend to build up muscle and fiber, moral and intellectual sharpness, poise and a mastery of conditions and problems. The introduction of better conditions in the road camp tends to the improvement of the whole morale and lifts the possibilities of greater efficiency in the construction work under scientific test during the labor day. The grasping of the simple forces well-known in group action, the injection of a "sporting" spirit of conquest over the impossible, and the personification of the ideals of struggle and combat which enter into the *wanderlust*, grip the excitable and propel forward the work, while producing, almost unperceived, a by-product in manhood, freed from the weaknesses of physical and mental deterioration and ready to face anew the industrial struggle of the community and win a place of value in it.

The student of road engineering who would be its master and ready for leadership in the coming years must mark well the studies of these human elements and develop within himself the ability to work out the human factors and produce new formulæ. In this we university teachers must be his guide and the road courses must take on these somewhat new and yet not uninteresting elements of road construction.

ESSENTIALS OF EARTH AND GRAVEL ROAD-CONSTRUCTION IN HIGHWAY ENGINEERING COURSES.

BY IRA O. BAKER,

Professor of Civil Engineering, University of Illinois.

The earth road is the cheapest road in first cost, and is by far the most common. It is a light traffic road, and only when the traffic becomes considerable is it possible to procure the money with which to improve the surface by the use of some foreign material, as gravel or broken stone. Fortunately, the best form for the earth road is also the best preparation for any improved surface. The improved surface, whatever its nature, is only a roof to protect the earth from the effects of weather and travel; and any preparation that will enable the native soil when unprotected to resist these elements will enable it the better to serve as a foundation for the improved surface. Because of its importance as a means of transportation, the earth road should receive careful consideration in any scheme of instruction in highway engineering. Unfortunately, the earth road has received almost no careful consideration, particularly its maintenance. The proper construction and maintenance of earth roads are highly important, but there is almost no literature on the subject; and therefore it is very desirable that instruction in such matters should be given not only to engineering students but also to agricultural students.

DRAINAGE.

The drainage of the road should be carefully considered; and the methods and reasons for securing adequate surface and underdrainage should be fully explained. If the phi-

losophy and the advantages of thorough underdrainage were better understood, it is probable that the most common road would be greatly improved, since this can be done at comparatively small expense for installation and at practically no cost for maintenance. Of course the underdrainage is to be obtained by the proper use of the so-called farm or porous tile. One not infrequently sees in an official bulletin or a good-roads pamphlet a grave consideration of all the devices employed before the introduction of the clay drain tile; but one might as well enumerate for the benefit of a person about to make a journey, all the means of transportation that have been used from the day of the ox cart with wooden wheels to the automobile.

The proper method of carrying small waterways under the roadway should receive attention, and emphasis should be given to the fact that small and inexpensive culverts are usually made too short. Doubtless some consideration should be given to the construction of what may be called large culverts or small bridges; but nothing very elaborate in this line should be undertaken in a course designated as road construction, although such instruction could properly find a place in a highway-engineering curriculum.

Maintenance.

It is in the maintenance of an earth road that instruction is most needed by both the student and the public. In this connection the advantages of continued maintenance over annual repairs should be pointed out. It should also be carefully explained that the road grader is a machine for annual repairs, while the split-log drag is an implement admirably fitted for continuous maintenance. Fortunately the road drag is cheap in first cost and easy to use; but unfortunately the advantages of its frequent use are not duly appreciated.

Development.

Many of those who seem to believe that the general introduction of hard roads is the panacea for all of our industrial

and social ills denounce the earth road as being entirely unworthy of respectable consideration; but a large proportion of the roads of all countries, even those having the greatest mileage of improved roads, have only an earth surface, and hence such roads are worthy of careful consideration. Besides, it is "whistling against the east wind" to attempt to persuade a community that has been content with poor roads to adopt hard roads. It has always been true that one improvement in any line leads to another; and when the people of a backward community learn the advantages of a well-kept earth road, they will be the more ready to take the next forward step in road improvement. Therefore all engineering students should be carefully instructed in the details of the construction and maintenance of the earth road and also of its near neighbor the gravel road.

SOILS AN ESSENTIAL IN COURSES IN GEOLOGY FOR CIVIL ENGINEERING STUDENTS.

BY LAWRENCE I. HEWES,

Chief, Economics and Maintenance, Office of Public Roads.

It is needless to consider in this paper the intimate relation which the subject of soils has to the subject of geology. The main object here is to discuss briefly the necessary information which civil engineering students should obtain concerning soils while undergraduates.

It must be assumed at the outset that time will not be available during the engineering course for the student to study exhaustively the entire subject of soils, and it is at once evident that the subject cannot be taken up to best advantage until the student is familiar with a considerable amount of physics, chemistry and general geology. Apparently then, the subject must be handled, in a four-year course, not earlier than the second half of the junior year, and the details of arrangement may well be left to the engineering faculties who understand the necessary balance which must be preserved in the engineering courses.

The direct bearing of the study of soils on engineering problems includes the following topics: (*a*) Soils as a condition for foundation; (*b*) soils as related to materials of construction such as sand, gravel, etc.; (*c*) soils for road surfaces and as determining elements in road drainage; (*d*) soils as an essential element affecting run-off from drainage areas; (*e*) soils as the basis of agriculture and as related to forestry. These subjects do not exhaust the relation of soils to all engineering operations, but they include the more important points of contact.

Study of Soils in College.

It is a common error on the part of engineers of matured experience to expect too much from students freshly graduated from engineering schools and colleges. It cannot be expected that undergraduate courses can present effectively all of the requirements of any of the above topics, but it ought to be made clear to engineering faculties that certain foundation work along these lines is essential. Whatever is taught to the undergraduate successfully tends to persist as a part of his mental equipment often in spite of his apparent neglect or indifference during the course. If, therefore, the very great importance of the subject of soils to his future work is emphasized along with the more commonly taught features of geology and other engineering subjects, the young engineer will not be at a loss when it becomes necessary to consider soil topics in some detail.

The undergraduate should, for example, be informed concerning the best available books on the subject of soil formation and should be informed of the existence of the Bureau of Soils in the Department of Agriculture at Washington, D. C., and, of course, concerning the great work of the U. S. Geological Survey and corresponding European organizations.

Taking up the subjects noted above in order, some attempt should be made to present under the subject of foundations not only a numerical table of tons per square foot or pounds per square inch of the safe loads on the various major classes of soils, but the student should also be given to understand why different soils offer different bearing powers to normal load. He should be taught to determine with some accuracy the nature of the geological soil division on which the construction is to be located, and he should be equipped with the necessary directions for an exhaustive study of the bearing power of soils, should it be necessary. He should also be informed of the action of alkaline soils on concrete masonry, and of the electrolysis of iron pipes, etc.

There never was a time in all engineering when the ability on the part of an engineer to judge the qualities of sand and

gravel are more needed in his equipment. You are, of course, all familiar with the tremendous importance of concrete in all engineering work, and you are also doubtless familiar with the great importance of selecting materials for making it. There should, therefore, be no question concerning the need of instructing students at considerable length on the geological process involved in the formation and deposition of sand and gravel. The need for physical and possibly chemical analysis of sand is not remote and is indeed quite likely to occur when important masonry structures are involved. The least that can be expected of the course in geology will include a most emphatic presentation of the main sources and causes of sand and gravel deposits; also, since the economic value of sand and gravel is continuously increasing, it is correspondingly imperative to equip young engineers with the knowledge necessary for locating any deposits of these materials, and to teach them conclusive methods of exhausting all possible areas of supply for a given job. This is especially important in road construction where material is a high-cost item.

Highway Engineering and Soils.

Your attention need scarcely be called to the present condition of the road improvement in the United States. We are spending annually nearly $200,000,000 for the construction and improvement of highways. This branch of engineering deals directly with soils. Drainage is the first and most important feature for road improvement. The knowledge of underground water and its transmission by various soils is indispensable to the highway engineer. Of the 2,200,000 miles in the country, about 2,000,000 miles are still earth roads. The enormous importance of these roads for our economic and social betterment is undisputed. They are built of soil. To illustrate the desirability of adequately understanding the nature of soils for road surfaces, we need only cite the recent practice, which has developed in the South, of surfacing roads with a mixture of sand and clay. A knowledge of the areas along the Atlantic States, the Gulf, and Central States, where

the alternate layers of sand and clay may be found, and the methods of detecting their presence, has afforded one of the most satisfactory applications of the knowledge of geology which young engineers coming into the Office of Public Roads have had. In this connection, it is proper to emphasize the fact that the demand for trained highway engineers at salaries from \$2,000 to \$3,000 throughout the United States is now greater than the supply. These men must have special training in the matter of soil conditions and soil formation.

Irrigation and the Soil.

With the growth of this country in population has come the movement for conservation of its resources. The subduing of arid lands for agricultural purposes by irrigation is now an established branch of the engineering profession in the Western States. The easy irrigation projects will soon be exhausted. Prices per acre for irrigation water will steadily advance. With these advances must come more refined determinations of the available water supply. Increasing study in the run-off from watershed areas, as conditioned by soils, will be needed. At the present time, the question of run-off is being studied diligently by engineers of mature experience, but the knowledge is all too meager for the needs of the future. If it becomes necessary to reforest watershed areas to retard the run-off, the question of soil will present itself from an agricultural standpoint, as well as from a mechanical standpoint.

We now no longer hesitate to place scientific agriculture among the skilled professions. If there is any question concerning the bearing of a knowledge of agriculture upon the equipment of the engineer, we have only to consider the duties which must involve upon the intelligent railroad man or the irrigation engineer. Engineering operations, as a whole, are undergoing a development which is characterized by increased attention to the needs of society as well as to the design of particular structures. The competition for railroad freight demands a knowledge on the part of the locating engineer of a productive area which must become increasingly exact as

time goes no. Nor can highway planning omit the agricultural conditions of traffic areas. A prominent railroad man remarked in this city within a year that a certain railroad, then under construction, might as well be in a tunnel or on a bridge, as through the unproductive belt of country it was then traversing. The report of an irrigation engineer is founded upon the knowledge of the source of water supply and the soil conditions under which the water is to be applied. His knowledge of soils must approach that of the expert agriculturist.

The items enumerated above serve to indicate the importance of the knowledge of soils to the civil engineer. They do not exhaust the list to which we might add questions of water supply, sewage disposal, alkaline soils, etc. The entire field of tunnelling and dredging operations has been omitted, as it goes without saying that although these subjects involve soil knowledge, they are already an integral part of civil engineering courses.

Soil Study in the Schools.

In looking over the catalogs of eight colleges and universities which offer instruction in civil engineering from the Atlantic to the Pacific States, and chosen at random, there were found three institutions which offer specific courses on soils. At Yale University, beginning with the second half year, there is given a course consisting of a series of lectures with supplementary reading, together with individual reports on assigned areas. This course runs for two hours per week until the Easter recess, and five hours in the spring half term. The course is one of twenty offered at this University.

At Columbia University, during the second half of the academic year, there is given a course on rocks and soils, consisting of two hours class room work and one hour laboratory work per week. This course deals with the origin, structure, constituents and variety of soils. There are thirty-seven courses in geology given at Columbia.

At the University of Illinois, course No. 12 is devoted to the geology of soils. This course is for five hours during the

second semester. It is planned especially to meet the needs of engineering students and is open only to such students and to students of ceramics. There are thirty-three courses on geology at this university. At the five other colleges and universities, there are from thirteen to thirty-five courses on geology, a few of which are closely related to a course on soils.

At Cornell University, course No. 31 is described as practical geology for civil engineering students. At Washington University, course No. 53 is devoted to building stones, clay products, and economic geology. Course No. 51 is entitled Practical Geology, and is for students in civil engineering. At Leland Stanford University, twelve courses are offered. Course No. 11 is arranged to suit the needs and qualifications of engineering students. These examples may serve to indicate what is now the attitude of our larger educational institutions.

Conclusions.

In conclusion, it would appear that the least that may be expected by the engineering profession from the faculties controlling geology courses in engineering institutions will include an adequate presentation of the literature and sources of information concerning soils, including a short description of the various organizations engaged in soil work and their publications, the subject of rock weathering, including the action of the atmosphere, the chemical action of water, the mechanical action of water and air, and the action of plants and animals, the subject of leaching and the major difference in the weathering of igneous and crystalline sedimentary rocks, the methods to be employed in investigating in the field and in recording observations, the relative importance of physical and chemical tests, and the thorough study of the soil mantle, whether originating through rock weathering *in situ*, or through plant growth, or from remote origin and transported by wind, water or ice to its present bed. In other words, a familiarity with as much of the subject described by Merrill in Part V of his text on rocks, rock weathering and soils and entitled "The Regolith."

FINANCIAL PROBLEMS IN HIGHWAY ENGINEERING, AN ESSENTIAL PART OF COURSES IN ECONOMICS.

BY GEORGE R. CHATBURN,

Head Professor of Applied Mechanics, The University of Nebraska.

Each cell in the honeycomb touches and forms a part of six others. To completely destroy one cell means the destruction of seven cells. To build up one lays a foundation for six more. The various subjects in a well-planned curriculum join together in some such way. Transportation and the problems arising therefrom form a part and may be studied through the media of several more or less closely related branches of knowledge. The peculiar problems of the engineer receive justly the most attention in our engineering colleges; but these are the central cell only, others cluster round about. The cell walls coalesce with the problems of lawyer, accountant, business manager, chemist, physicist, geologist, bacteriologist, rhetorician, historian, sociologist, economist. It is a trite saying that to know everything about something it is necessary to know something about everything.

PRIMARY TRANSPORTATION.

Perhaps the most important problem connected with the highways is the cost of primary transportation. Secondary transportation, the transportation on railways, canals, ocean and lake ships, has for years received the attention of the economist, as well as that of the lawyer, the scientist and the engineer. Secondary transportation being almost wholly a matter of private enterprise, the cost of it has finally resolved itself largely into a question of rates and fares, their economic and profitable adjustment, and the very many elements that

enter into them. State and interstate commissions are organized with munificent money chests back of them to study these questions. Economists have written articles, treatises and texts covering them, but the cost of primary transportation, upon the wagon roads, from the field to the market and from the market to the home, has received but scant consideration, and what little has been done has been done by the engineers. The question covers an extensive territory; it opens up many subfields which might very properly be considered under this caption: For example, economic location; construction; traffic census; effect of grades, rise and fall; road surfaces; horse, steam and gasoline motive power; durability; maintenance; effect upon neighboring industries, location of factories, intensive farming; sanitary and psychological considerations of the healthfulness and germ carrying proclivities of various kinds of roads; the effect of dust on man, beast, and vegetable, as well as the economic and engineering aspect of the dust on the road itself; the neurotic action caused by noise and by pleasant and pleasurable drives. All these unite with purely sociologic questions, such as the effect of better roads on the social intercourse of the people, public schools, churches, mail delivery, and the diversions of various kinds, tending to influence society, raise the standard of living, and better the condition of mankind.

To be sure these things are being handled in engineering colleges, if handled at all, as purely engineering subjects; but many of them might well be considered and made to stand out with more prominence in the departments of economics, sociology, bacteriology and psychology. The cost of primary transportation is so hidden that it, if thought of at all, is merely an incident of the cost of production. If it were segregated and discussed as a problem in marketing, the principles of accounting applied and each operation debited with its share of the cost of production, the economic features would be seen to be of as much importance as those of rates and fares in secondary transportation. The economist would then gladly incorporate it in the "science which treats of those social phe-

nomena that are due to the wealth-getting and wealth-using activities of man."*

Motor Vehicles.

As motor trucks become more plentiful new phases of this problem will present themselves for solution. Even now the automobile is something to be reckoned with. In Nebraska there are registered more than 40,000 machines,† about one to every thirty persons, that is, every tenth family in the state possesses an automobile, and Nebraska does not stand particularly high among the states in the aggregate number of motors registered and never will, because a large portion of that state for physical reasons can never be thickly settled; yet this one western state has invested in this one item approximately forty millions of dollars. Tractors, owned by farmers in coöperation, or by individuals or companies as freight cars are now owned, may soon haul the grain to the railway station; thus with the increase of motor vehicles will be inaugurated a further division of labor. Even now farmers are looking upon the automobile as an economic investment on account of the great saving in time required for the necessary travel incident to farm life.

Highway Financing.

But there are other problems pertaining to highway engineering that may more clearly fall within the domain of the economist. There is the question of financing road projects. The road, the land itself, the labor and materials put upon it to make it usable, the horses and vehicles employed in transportation, may be likened to a production machine in the great commodity factory of the nation; as such its value becomes productive capital. The economic principles relating to productive capital, to the rent of land and its capitalization, wages of labor used in construction and maintenance, the finan-

* Ely, "Outlines of Economics."

† 40,250, June 1, 1913. Population, 1,192,214; 1910 census.

cing of enterprises, the borrowing of money, interest and profits, are all closely associated and are in the legitimate domain of the economist. A physical valuation of a road and equipment might be made to determine the amount of this productive capital and a fair interest thereon charged against the production cost of crops marketed over this road. The rental value of adjacent lands, since the roadway itself is not rentable, would be taken as a basis for computing the value of the right-of-way. The wages of labor and the cost of materials would necessarily come into the problem in computing the replacement value, and so on for the remaining items to be considered.

The economics of long-term bonds should be explained as thoroughly as may be possible to those who have the voting of such bonds; the highway engineer and the road officials should be prepared to make this explanation. It may be desirable to compare the construction bonds to corporation capital or corporation interest bearing preferred stock; to determine whether or not this road, considered as a productive business organization, is over-capitalized; in other words is the stock watered? The economic question of issuing long-term bonds, which may run even longer than the life of the road, is already a vital problem in some of our states. The payment and amortization of bonded and other debts are likewise interesting topics.

Taxation and Highways.

Another problem particularly economic is that of a just and equitable system of highway taxation. A metered service is said to be ideal but toll gates have gone out of use. A general averaging of expenses is frequently easier to administer; as in the case of the postal system where a two-cent stamp carries a letter one or one thousand miles. Present tendency, however, seems to be toward metering as shown by the zone scheme in the new parcel post. So the roads of our country, and of most civilized countries, have become "free." The consumer of goods, in the cost prices, eventually pays all the

hidden charges for transportation. Should the grocer make a separate charge for each item of delivery according to weight and distance as does the express company? Would it be fairer to tax each vehicle as is attempted in the automobile license? Here again comes in the question of productive capital—the wagon and horses of the grocer, for example, and consumptive capital—the automobile used solely for the pleasure of the owner.

Still other problems are these: The equity of special taxes for the construction of roads and pavements; methods of determining the benefits derived that the taxes may be legally distributed; the propriety of levying special assessments for maintenance; and the wisdom, from an economic standpoint, of retaining from the contract price a "guarantee" for a term of years.

Governmental Aid in Highway Construction.

Still another present day problem is the question of state and national aid for highways. Already numerous bills have been introduced in Congress for the construction of specific trunk line highways, one of the most recent schemes being the suggested bill of Senator Bourne whereby one billion dollars is appropriated and divided among the several states for highway improvement. The government has for years been expending large sums of money on its harbors, and is at present building the great inter-oceanic canal at a cost of $400,000,000. Should the internal primary transportation facilities be assisted by national aid or left entirely to local support? Are there any economic or sociologic reasons why one class of transportation should receive national aid, the other not? Will the production of capital through the opening of better highways by the general government be distributed with sufficient equity among the people to warrant the payment for these highways by general taxation? Would it be better to have trunk line roads constructed by private enterprise, as they would be used largely by automobilists,

with a toll charge? This last opens up the argument for and against government ownership. Which is most efficient? Which will with greater elasticity meet the demands of business? Will government management be debauched by politics? Will private ownership develop capitalistic control of politics? Will it bring personal discrimination? Which is better on the whole, private ownership managed for profit or public for service? To whom should the unearned increment due to better roads accrue, if to society how can this be accomplished?*

Highway Economics.

To the highway engineer individually there are in economic science other things of import. The engineer being a constructor is a producer. The science of economics treats of production and the underlying factors of land, labor and capital. The operation of construction requires division of labor, needs business organization and management. The constructor must purchase materials and supplies and in a way sell these to the owner, in the case of roads, the public; consequently profit-making and risk-taking constitute a legitimate part of his work. He would be the better if he understood the scientific nature and economic meaning of value, objective and subjective, the relation between value and price, supply and demand. A knowledge of the financing of undertakings of magnitude, the procedure necessary to pursue, the legal niceties that must be provided, may prove valuable to many engaged in road construction.

The constructor deals largely with the public through the public's officials, therefore he must have a knowledge of civil government and political economy in its more restricted sense as those things which pertain peculiarly to the body politic, to government. It would be well also for him to understand the influence of government upon economic relations and likewise something of intra-state, inter-state and international trade, although these may be somewhat remote from the subject.

* Compare Ely's "Outlines of Economics," p. 480.

Also our roads in a way being government monopolies the road engineer would be better for a scientific study of monopolies and their classifications.

Engineering from its inception has and is an economic science and many topics of an economic nature will and should be taught in engineering classes, as for example, the economy of road location, of materials, of labor, and the study of particular conditions affecting these. On the other hand many of the things which have been mentioned could well form the nucleus of a course in the "science of the laws and conditions which regulate the production, distribution and consumption of all products, necessary, useful or agreeable to man, that have an exchange value."*

* Century Dictionary.

HIGHWAY MATERIALS—LABORATORY WORK IN THE CIVIL ENGINEERING COURSE.

BY FRANK H. ENO,

Professor of Municipal Engineering, The Ohio State University.

The objects of an engineering education are fourfold, namely, in the order of their importance:

1. To give to the student a training in the powers of reasoning and thinking.

2. To familiarize him with the fundamental underlying principles and methods of engineering practice.

3. To give him a training in applying these principles to any and every engineering problem which may be presented to him for solution.

4. To furnish him through texts, lectures and his own investigations a growing fund of information and experience from older men to widen his limited experience during the early days of his initial practice.

The Place of the Highway Materials Laboratory.

Where in this analysis of an education does the work in a highway materials laboratory fit? It touches No. 2, is pertinent to No. 3, and adds to the experience sought in No. 4. It familiarizes the student with laboratory methods on this class of materials—bitumens, road stone, brick paving block, etc. It shows him machinery especially designed to make the investigations necessary to a better understanding of road materials. It gives him an insight into the action of a number of materials placed under conditions quite different than those ordinarily met under usual construction practice.

The student through his physics, geology, mineralogy, chemistry and crystallography has learned something of hardness,

toughness, elasticity and the interlocking structure of mineral masses. But a short course in the laboratory gives him concrete illustration of much which he has absorbed in a theoretical way. It serves to fasten upon him much that has been only dimly seen or is imaginary to him, in part at least.

He finds that real hard stone or brick may not mean durable materials. That toughness alone may be little more than "rubbery" consistency. That porosity in a material may not mean that such a material will rapidly disintegrate under weathering conditions, or, it may mean that it *will*.

Highway laboratory work should give the student some confidence in his abilty to judge a material in a rough way, classifying it broadly as useless or more or less valuable for specific purposes. By personal inspection, even in a casual way, it should enable him to say that a specific rock or paving block is either altogether too soft, friable, porous, etc., to serve the purpose, or else that it would do fairly well, or could be expected to give excellent service. In other words, the laboratory work should make the student sufficiently familiar with the ordinary road materials so that he will at least not be a perfect ignoramus when he meets the material as he first goes into active practice. It must be granted that his casual knowledge of the bitumens and oils must be handled circumspectly.

Should there be a laboratory course in the highway testing laboratory for civil engineers? Yes, but it should be made short and to the point, using from three to five afternoons in the individual course assigned to the study of the highway subject. The class division should be small, but eight to twelve students being taken into the laboratory at one time. Close supervision by the instructor should be enforced and some of the more common but important tests should be carried on. These might include the rattler test on paving block, illustrating from samples before and after testing how the different materials stand the test. The student then should be asked to pass judgment on certain specimens, giving reasons for his conclusion. He should then be shown wherein he may have made misjudgments.

Other tests, such as the abrasion test on macadam stone, the cementing test on stone dust, specific gravity and penetration tests on bitumens, should be made. A few of such general tests carried on by the instructor and students working together, the instructor commenting on each phase and the probable variant results with different sample materials before them which have already been tested, comparing with the sample under test, *will,* in the writer's opinion, give better results to the student than if he is called upon to make one lone test by himself. The student working on a single test can not intelligently compare it with other tests which he has *not* made and the value of the work will be small to him.

The other side of the laboratory question may be championed by some, namely, to have the student make a sufficient number of tests to give him a comparative knowledge of the material. To this, reply is made, the amount of important work to be done in the civil engineering course is so great, the time allotted is so small, the capacity of the student to accomplish and digest results is so limited, that any extended laboratory course is precluded. A well-balanced civil engineering course can not afford to give more than one credit hour to road-laboratory work and the writer would limit it to from three to five afternoons in the laboratory as previously stated.

In conclusion, allow me to remark that the present civil engineering course, as given in the majority of our best state universities, is sufficiently broad and at the same time covers so much in detail that there is little room left to add anything for a special course in highway engineering. A three-hour course through the year would amply supply any needed special work to fit the student for highway work. Of course one can go into special investigations *ad infinitum* but these do not necessarily make the practical road builder more successful.

CHEMISTRY OF BITUMINOUS MATERIALS IN THE CIVIL ENGINEERING COURSE.

BY PREVOST HUBBARD,

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Both native and artificial bitumens have, within recent years, become such important materials of construction that some knowledge of their occurrence, preparation, and characteristics is now necessary to the civil engineer who wishes to specialize in highway engineering. From personal observations covering highway treatment and construction in many sections of the United States, the author feels safe in stating that millions of dollars are being inadvisedly expended, if not practically wasted, in this country, each year through lack of such knowledge on the part of highway engineers. It is estimated that at present considerably over one million dollars per day of public moneys is being invested in this country in road construction and maintenance, a very considerable portion of which is used for the purchase of bituminous materials, and the construction of bituminous highways. As the success or failure of these highways is largely dependent upon the judgment of those engineers who are responsible for the selection and proper application of the bituminous materials, the importance of adequate instruction regarding these materials must be apparent.

Bituminous Materials in the C. E. Course.

Just what instruction of this nature should and could be given in the civil engineering course, without consuming time necessary for the more general subjects, is a matter for serious consideration. Bituminous road materials are as complex in

composition and characteristics as any class of matter can well be. While they consist mainly of hydrocarbons and their derivatives, many of which have been identified either as individuals or groups, they are, as a class, difficult to study because they are made up of complex solutions, emulsions and mixtures of practically innumerable combinations of hydrogen and carbon, to say nothing of oxygen, nitrogen, sulphur and other elements. It is, therefore, a difficult matter even for one who has made a special study of these materials, to impart his knowledge to the average civil engineer or engineer student in such manner that the essentials of the subject may be grasped and retained in the limited time which can usually be devoted to such instruction.

Course in Bituminous Materials at Columbia.

In the post-graduate course in highway engineering inaugurated at Columbia University, in 1911, the chemistry of bituminous materials is given in two full courses. These courses were planned with considerable care and forethought by Professor Arthur H. Blanchard and the author with a view to presenting the subject to the average graduate student in civil engineering in such manner that it could be grasped and retained by him with no previous training in chemistry other than that given in the usual undergraduate course.

For a number of reasons which need not be considered here, it was decided to concentrate these courses under two periods of two weeks, or seventy-two consecutive working hours each.

As at present given, the first-year course consists of lectures, demonstrations and seminars covering the following subjects: Classification of dust preventives and road binders; inorganic dust preventives and road binders; organic non-bituminous dust preventives and road binders; hydrocarbons; classification of bitumens; petroleums and petroleum products; semi-solid and solid native bitumens; tars and tar products; manufacture of road oils and oil asphalts; refining of native asphalts and manufacture of asphalt cements; manufacture of coal tar dust preventives and road binders; manufacture of water gas

tar dust preventives and road binders; demonstrations of methods of examination and analysis; extraction, evaporation, distillation, filtration, and determination of specific gravity, melting point, flow point, consistency, penetration, ductility, solubility, flash and burning points, fixed carbon and paraffin.

The prerequisite for this course consists of the usual general course in inorganic chemistry, covering the laws of chemical combination, history, occurrence, preparation, and properties of the elements and their principal compounds, which is given undergraduate students in civil engineering.

The second-year course consists of lectures and laboratory work covering the following subjects: Determination of chemical and physical properties of light, medium and heavy oils, residual asphaltic and semiasphaltic petroleums, bituminous emulsions, oil asphalts, natural asphalts, fluxed natural asphalts, rock asphalts, coal gas tars from horizontal, inclined and vertical retorts, water gas tars, coke oven tars, combinations of tars and asphalts, bituminous aggregates and by-products used in the construction and maintenance of roads and pavements; analysis of unknown bituminous materials; interpretation of results; specifications covering the use of bituminous materials. The prerequisite for this course is the first-year course above described.

Results Achieved.

The results so far obtained have been very encouraging to the author. The courses have been attacked by the students with intelligence, application and an interest that has been extremely gratifying. As previously stated, however, the subject is a difficult one to teach as well as to learn, and the author has felt somewhat handicapped in his work by the necessity for spending valuable time on certain elementary subjects which he believes could be consistently given in the undergraduate course with benefit not only to students who contemplate taking the graduate course but also those who are unable to do so.

Recommended Course.

He would therefore recommend an undergraduate course in chemistry which, while more comprehensive than the prerequisite above mentioned, would consume but little more time and prove of greater value to the civil engineer student who intended to make highway engineering his profession. Such a course would include the following subjects:

I. General Chemistry:
  (a) Laws of chemical combination.
  (b) History, occurrence, preparation and properties of the elements.

II. Inorganic Chemistry:
  (a) Preparation and properties of the principal inorganic compounds with special reference to those occurring in ordinary structural materials.
  (b) Classification and manufacture of inorganic materials of construction, such as iron, steel, cement, etc.

III. Organic Chemistry:
  (a) Classification of and relation between the principal series of hydrocarbons, with little or no reference to their derivatives.
  (b) Occurrence and properties of the native hydrocarbon deposits, such as petroleums, malthas and asphalts. (This subject to be treated in an elementary manner.)
  (c) Manufacture and properties of such hydrocarbon products as coal gas, carburetted water gas, and coke, together with their by-products, especially tars. (This subject also to be treated in an elementary manner.)

While comprehensive, this course could be treated concisely as a whole and would tend to eliminate the very natural question regarding the necessity of the course in chemistry, which is apt to suggest itself to the undergraduate student in civil

engineering and which tends to detract from his interest in chemistry as presented in the usual abstract way.

The value of such a course will be greatly augmented by brief laboratory courses in qualitative and quantitative analysis, dealing principally with the structural materials which had been previously studied. Such laboratory instruction is not an absolute necessity but experience at Columbia University has been most encouraging with those students who have had some laboratory instruction in qualitative and quantitative analysis.

The subject of the chemistry of bituminous materials is one of growing importance to the civil engineer, and the author hopes that it will receive serious and careful consideration by all who have an interest in the promotion of engineering education.

HIGHWAY SURVEYS IN THE CIVIL ENGINEERING COURSE.

BY HENRY B. DROWNE,

Instructor in Highway Engineering, Columbia University.

The fact that many technical graduates are entering the field of highway engineering has awakened educators to the importance of this branch of engineering. The action of this society in devoting meetings to the special consideration of the subject of highway engineering is evidence that this body appreciates the situation. Highway engineering is beginning to be regarded just as distinct a specialty as railroad, bridge or sanitary engineering.

Why Teach Highway Surveying?

There are many subjects of study in highway engineering that can best be taken up as graduate work. Field work in surveying, however, should not be given in a graduate course, but in the undergraduate civil engineering course. It may be the contention of some educators that field work in highway surveys is unnecessary; that when a student has had field work in plane surveying and in railroad surveying, he is perfectly able to cope with problems that will develop in making surveys of highways. To a certain extent this is true since highway surveying like railroad surveying is nothing more than the special application of the fundamental principles of plane surveying. Considerable time, however, is devoted to the subject of railroad surveys in all technical institutions, presumably to illustrate some of the problems arising in railway location and to familiarize the student with the practical methods of doing the work. Highway surveys and railroad surveys are different in several respects. If the desire exists

to emphasize fundamental principles and it is believed that highway engineering is just as important as railroad engineering, why should not some time be devoted to highway surveying?

Special Features of Highway Surveying.

Some of the features wherein highway surveys differ from other surveys will be mentioned. The relation of the transit line to other parts of the work is variable. Sometimes it is important to make the transit line coincident with the center line of finished work, while at other times this refinement is unnecessary. The shape of the earth's surface within the limits of the survey is obtained by taking cross-section levels at stated intervals rather than by running in contour lines. Grades are staked by recording the elevation of the finished center line grade on stakes driven where they will not be disturbed during construction. Although it is usually advisable to locate curves of any length by deflection angles, many short curves may be just as accurately and more rapidly located by other methods. A special form of notes is used for recording the information obtained in the field. It is also important that one should appreciate the standards of accuracy which each part of the work demands. There are several important factors governing location which can be emphasized in making a survey such for instance as foundation, æsthetics, sight distances around curves and at other points of danger, disturbance of trees and property adjoining the highway.

Practical Suggestions.

In view of the foregoing the author would suggest that part of the time now devoted in our engineering courses to railroad surveying be used for making the survey of a highway. A comprehensive idea of the methods employed could be obtained if a survey of an existing highway one quarter of a mile in length was selected. In order to emphasize some of the salient factors of good location, previously mentioned, it would be

preferable to select a portion of an unimproved highway where these factors would have to be considered. The student should be required to plot the survey, establish the grade and make an estimate of the amount of work to be done.

The time required to do the work outlined above should not be more than thirty hours of actual work. The strength of the course in railroad engineering would in no way be impaired by decreasing the time now allotted to the field work in this subject an amount equivalent to thirty hours of actual work. It would simply mean making a shorter railroad survey. It is believed that by making a highway survey the student will familiarize himself with certain features of highway engineering that otherwise would not be appreciated.

Discussion.

Professor G. R. Chatburn: I agree with the chairman in the idea that there is no urgent need at this time for special courses in highway engineering, *per se*. That is, I believe it would not be good policy to formulate a four year course leading to the degree of Highway Engineer, or B.Sc. in Highway Engineering. The same principles underlie the ordinary course in civil engineering as would such a course in highway engineering. No good civil engineer ought to hesitate to undertake the construction of a road. That there is a demand for highway engineers can not be denied; that the college should furnish these engineers goes without saying. Certain options in the civil engineering course should be allowed to cover this demand. The preliminary survey and location of a railroad and a highway vary too little to warrant special classes in each subject; likewise, the laying out of curves, the staking of cuts and fills, the methods of grading, the calculation of earthwork and overhaul, and the mechanics of culverts and bridges. But instead of dwelling upon track, switches and turnouts, the highway student would need a knowledge of road surfacing and the preparation and testing of road materials; this might require a knowledge of geology

and chemistry in advance of that given the ordinary civil engineering student. And similarly for other subjects. However, with a few options, as before stated, it will be possible for the college to meet the demand for highway engineers without creating a specialized group of courses called highway engineering concurrent with and duplicating, partially at least, our present civil engineering instruction.

Dean F. E. Turneaure: It is a point worth noting that the demand for highway engineers is almost a new thing, and is increasing very rapidly at the present time. Owing to recent state legislation, it would appear that no less than 150 young men will be required in highway work in each of several states, in the central part of the United States, within the next year or two. The demand for experienced men can hardly be met, but many schools will soon be prepared to meet the demand for beginners in this line of work as well as in any other branch of civil engineering. The present demand for experienced men has perhaps led to over-emphasis of practical knowledge on the part of graduates, which will not obtain when the work becomes sufficiently organized so that the young college graduate can get his practical training in the same way as in other branches of engineering. There seems to be no sound reason why the instruction in highway engineering should go further in teaching practice than in other branches except, possibly, to meet the present special demand. It is our belief that highway engineering should be given relatively about the same emphasis in a college course as other branches of civil engineering.

Professor Clark E. Mickey: At the University of Nebraska we now have two courses that could be called highway engineering courses. I would be pleased to hear from the representatives of the other institutions on this subject, both as to the number and names of such courses and as to the methods for teaching them.

In the civil engineering department we have a two-credit-hour course named roads, streets, and pavements which is taught by means of lectures, assigned readings, and reports.

The Textbook on Highway Engineering by Blanchard and Drowne is used in this course. Two hours attendance and four hours preparation per week for one semester are required.

In the department of applied mechanics we have recently added a two-credit-hour course named road-materials testing. The catalog description of this course is as follows: Examination, classification, and testing of road and pavement materials including rock, gravel, sand, clay, earth, paving brick, wood blocks, stone blocks, oils, asphalts, and tars. The testing of cement concrete, bituminous concrete, and sheet asphalt. The building of a miniature road or pavement model, illustrating the successive steps of construction as well as the finished road or pavement. One hour attendance at lecture and two hours preparation per week for one semester. Three hours laboratory per week for one semester. Two hours credit. Additional credit may be earned by special arrangement.

We have recently installed two road-materials testing laboratories, one being equipped with a Dorry hardness machine, a diamond core drill, a grinding lap, a diamond saw, a Page impact testing machine, Deval abrasion machine, a ball mill, cementation briquette-forming apparatus, Page impact machine for testing cementation, a standard brick rattler, scales and all necessary apparatus for testing the properties of non-bituminous road and pavement making materials. The other is equipped with all the necessary machines and apparatus for the examination, classification, and testing of all bituminous road materials and bituminous road and pavement surfaces.

Professor W. C. Hoad: A point that impresses me in connection with this subject is the relation of the engineering departments in state universities and colleges to state and county highway work. In many states the annual expenditure for highways is already one of the largest items of the state, county and township budgets, and in most sections the yearly appropriations for this purpose are constantly increasing in magnitude. In the past the bulk of this money has been expended by men without thorough training in the fundamentals of highway development and construction, and it is pretty

generally believed that the relatively small return that oftentimes has been obtained from expenditures for highways has been due largely to this fact. Is this condition to continue indefinitely into the future? It seems to me that state supported schools of engineering have a definite responsibility in this matter, as well as an attractive opportunity for the performance of a significant public service.

Moreover, in some sections of the country, notably in the Mississippi valley, the tendency appears to be strongly in the direction of state leadership in highway matters through the agency of state highway departments, these state departments having affiliated with them well organized and effective county engineering offices over which they exercise some degree of supervisory control. But the realization and successful operation of any such plan are dependent upon the maintenance of a supply of suitably trained engineers, and to provide these engineers, trained in highway work, is a duty no less than an opportunity for the state supported schools of engineering. I know of one state in which a law was passed creating an engineering office in each of the more populous counties for the express purpose of placing existing road work on a better basis, and especially of developing a well balanced system for the progressive improvement of the highways of the state. So far the law has fallen far short of the degree of success it should have attained, and in some quarters has met with the most determined opposition; the chief reason being that partly as the result of an inadequate salary schedule but partly by reason of an almost total lack of properly trained engineers, available for the work, the men appointed to the new positions were incapable of carrying out the full purpose of the law.

It requires little argument to show that, in general, highway engineering positions in the past have been poorly paid, and that they have oftentimes been surrounded by conditions not attractive to the best men and not conducive to first class work; and that such conditions still exist to some extent, particularly with reference to the compensation allowed for work of this kind. There is great need for improvement in both

these respects, and for a better recognition by the community of the large importance of sound and constructive highway work. But in order to do work of this character men must be trained for it, and it would seem to be the proper function of a state engineering school both to furnish a supply of suitably trained highway engineers, and to assist the communities of the state toward a more adequate conception of the importance and value of the services of such men.

A member has asked for information concerning courses offered in highway engineering. At the University of Michigan there is a two-hour course in roads and pavements, which all civil engineering students are required to take. In addition, there is a two-hour course in engineering of country highways, a course of four hours per week in laboratory tests of paving and road building materials, and a two-hour lecture course in street cleaning and certain other phases of municipal work not included in other courses. These last named are not required courses, but are ordinarily elected as senior optionals by men heading in the direction of municipal or highway work.

REPORT OF COMMITTEE ON NECROLOGY.

WARREN BABCOCK.

1866-1913.

Professor Babcock was born at Ypsilanti, Mich., September 15, 1866 and died June 3, 1913. His elementary education was obtained in the public schools of Milan, Mich., from whence he came directly to the Michigan Agricultural College, graduating with the class of 1890. In the following year, he became instructor in mathematics in his alma mater, and in the course of the succeeding years he was advanced to full charge of the department. Besides his departmental duties, Professor Babcock had been for many years secretary of the faculty, which work brought him into intimate connection with the administrative affairs of the college. In both capacities his associates have recognized his ability and efficiency.

Professor Babcock always had the courage to stand fearlessly by his convictions. The following quotation from a short characterization in a recent 'Wolverine' epitomizes his character: "When he talked he looked one straight in the eyes and a square deal followed."

To the community his death results in the loss of a public-spirited and estimable citizen. In the early years of the little city adjoining the campus, when many peculiarly difficult problems demanded careful solution, Professor Babcock, as mayor, gave unsparingly of his time and ability, and rendered conspicuously efficient public service. In more recent years he has been a member of the local board of education. In these official capacities the same characteristics, so markedly manifest in his college duties, predominated. No better testimony in appreciation of his work can be offered than that of the reluctance with which his fellow citizens consented to heed his personal desire to be relieved from the responsibility of public office.

During the last five years of his life Professor Babcock was an interested member of this society.

A. R. SAWYER.

ARTHUR J. FRITH.

1852-1913.

Professor A. J. Frith, who died in Chicago on November 12, 1913, was born in Philadelphia, Pa., on February 23, 1852. He was a graduate of the Rensselaer Polytechnic Institute, where he received the degree of C.E. As a young man he worked in steel and rolling mills and was sent to England for special information in this line. He then taught thermodynamics and mechanical engineering subjects at Lehigh University, which work he left to become designer, erector and finally assistant chief engineer on government work in connection with the Mississippi River Commission. He was next a designer for the Newark (N. J.) Machine Tool Works and here originated special methods for calculating the strength of machine-tool parts. He was a special designer on coal-handling plants for the C. W. Hunt Co. of New York and followed the same line with the Trenton (N. J.) Iron Co. He was assistant chief engineer and designer with the New York branch of the Diesel Engine Co. and secretary of the Washington Co. (N. Y.), steam-plant contractors. As a consulting engineer in New York City he specialized on research work in heat, gas and steam engines. Later he accepted the position of Associate Professor of Mechanical Engineering at the Armour Institute of Technology, which he held at the time of his death.

Professor Frith was the author of a number of scientific papers and secured several important patents. His special research was in "boiler efficiency," "regenerator efficiency," "true gas-engine efficiency" and "entropy analysis." He was a member of the American Society of Mechanical Engineers, the Society for the Promotion of Engineering Education and the Society of Automobile Engineers.

THURSTON M. PHETTEPLACE.

1877-1913.

Thurston M. Phetteplace was born May 3, 1877. He was educated at the English and classical high schools of Providence; and received from Brown University the degree of Ph.B. in 1899 and of M.E. in 1900. Columbia gave him the degree of A.M. in 1909. At the time of his death he was associate professor of mechanical engineering at Brown University. In connection with Professor Brooks and the writer he was engaged in consulting work under the firm name of Kenerson, Brooks and Phetteplace. His specialty was automobile construction and gas-engine design. He was a member of Phi Beta Kappa, Sigma Xi and the following societies and clubs: American Society of Mechanical Engineers; Society for the Promotion of Engineering Education; Providence Association of Mechanical Engineers, of which he was President; University Club; Flat River Club; Providence Art Club; Swastika Canoe Club; Edgewood Tennis Club; and the Phi Delta Theta Fraternity. He had contributed to the technical press, and to the Proceedings of the American Society of Mechanical Engineers.

His genial disposition endeared him to a large circle of friends and his sudden death on September 7, following an operation for carbuncle, deprived the University of a very able teacher. W. H. KENERSON.

CALVIN MILTON WOODWARD.*
1837-1914.

Calvin M. Woodward, dean emeritus of the school of engineering and architecture of Washington University, St. Louis, Mo., died on Monday, January 12, 1914. During the morning of the previous Saturday he visited the benefactors of an educational philanthropy of St. Louis in which he was deeply interested. After his return home he was suddenly stricken with apoplexy which soon produced coma and without regaining consciousness he passed peacefully away at 2 p. m. the following Monday.

Professor Woodward was born in Fitchburg, Mass., August 25, 1837. He took his A.B. degree at Harvard in 1860, with Phi Beta Kappa honors. Later he was given the degrees Ph.D. by Washington University and LL.D. by that institution and also by the University of Wisconsin. He was principal of the Newburyport, Mass. High School from 1860 to 1865, but in 1862 was given leave of absence to enter the war, in which he served as captain of Co. A, 48th Regiment, Massachusetts Volunteers during 1862–3 and participated in the storming of Port Hudson. He was vice-principal of Washington University Academy from 1865 to 1870 and from 1870 to 1896 was Thayer professor of mathematics and applied mechanics and dean of the polytechnic school (afterwards known as the school of engineering and architecture).

In 1896 on account of his many duties, including the active directorship of the St. Louis Manual Training School, which he founded, he resigned the deanship. This office he resumed again in 1901 and bore the three titles mentioned above until he retired from active service in 1910, near the end of his seventy-third year and after forty-five years of devotion to Washington University and its interests.

Dr. Woodward held many conspicuous positions in St. Louis, in Missouri, and in the various scientific societies to

* This memoir was prepared by C. A. Waldo, Thayer Professor of Mathematics and Applied Mechanics, Washington University.

which he belonged. He was president of the board of regents of the University of Missouri; was for many years a member of the board of education of St. Louis and a part of that time its president; was president of the American Association for the Advancement of Science, and president of the North Central Association of Colleges and Secondary Schools. He joined this society in 1894, was a member of its council 1899–1901, vice-president 1901–1902, president 1902–1903, and chairman of the committee on industrial education for many years. He was a frequent contributor to the proceedings of this society, of the American Association, and many other societies, but the mere enumeration here of the titles of papers would take too much space. His earliest published book was "The History of the St. Louis Bridge," a worthy record of the first of the famous achievements of James B. Eads. This history is and must remain a classic in its field. He also wrote two books upon Manual Training.

Since his retirement in 1910 he has written a notable text-book on rational and applied mechanics. This book, which grew out of his life-long experience as a teacher of mechanics, will soon pass to a second edition.

In all the manifold activities of Dr. Woodward's long, useful and distinguished career, during which he faithfully served two generations, his main purpose and greatest ambition was to be as he himself once said "a true and faithful teacher of men." It was his consuming desire to live, as a directing force for good, in the hearts and lives of those he taught after he himself had gone from among them.

APPENDIX.

DEPARTMENTAL ORGANIZATION.

BY HUGO DIEMER,*

Professor of Industrial Engineering, The Pennsylvania State College.

An important feature of modern industrial organizations developed as the result of the investigations made within the last few years relating to the application of the principles of scientific management to administrative problems, is the complete remodeling of positions of higher responsibility.

It has come to be a recognized feature of successful industrial organizations that there must be opportunity for progressive promotion continuously throughout the active life of service of the more responsible heads. A recognition of this principle has resulted in the creation of numerous general administrative offices in the larger industrial and railway corporations. It was recognized that one of the worst features of specialization and departmentalization was that a capable man progressed and was promoted until he came to be head of a specialized department. Having reached this goal he was confronted by a stone wall under the old system of organization. As indicated, in the larger industries and railway corporations this condition has been remedied. Unfortunately in educational work it has not been remedied. We have gone on increasing the number of departments, sub-dividing existing departments, removing from the jurisdiction of the department head everything excepting the bare technology of his specialty.

Until we recognize that department heads should be men with human interests, men who are active citizens, who take an interest in the economic, social and even political aspects

* Discussion of the paper on Academic Efficiency by H. S. Person, page 39.

of their profession, we must expect popular fiction to abound with caricatures of college professors, cartooning them as narrow individuals who have no interest in the world outside of scarabees and similar minute specialties. This defect in the educational organization largely accounts for the fact that men with the kind of instincts and abilities which tend to make them individuals of the type known as men of affairs do not remain in educational work, unless the rare opportunity arises of securing positions where they can obtain rank and salary together with adequate responsibilities and broad interests worthy of men of their type.

To indicate how we have narrowed our responsibilities we need but glance for a moment at the comprehensiveness of the old-time department of civil engineering. At present we have instead of a department of civil engineering, specialized departments in mechanics, highway engineering, sanitary engineering, hydraulic engineering, etc. Similarly in the case of mechanical engineering, instead of the old-time professors, who were recognized leaders in the country and familiar with the broader economic and social aspects of their work, we have now professors of thermodynamics, of machine design, of steam engineering and of other sub-specialties.

The same is true in the college of liberal arts. Under the old organization the professor of history was an all-around broad-gauged man, who understood economics and politics. Under the present organization we have distinct departments of economics, political science and various sub-departments in history, such as American political history, European constitutional history, etc.

I suggest as a most desirable question to be answered by a committee to be appointed by this society the following:

"How can we plan a system of departmentalization and promotion in the colleges so that there shall be continuous opportunity for progress for the capable man?"

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